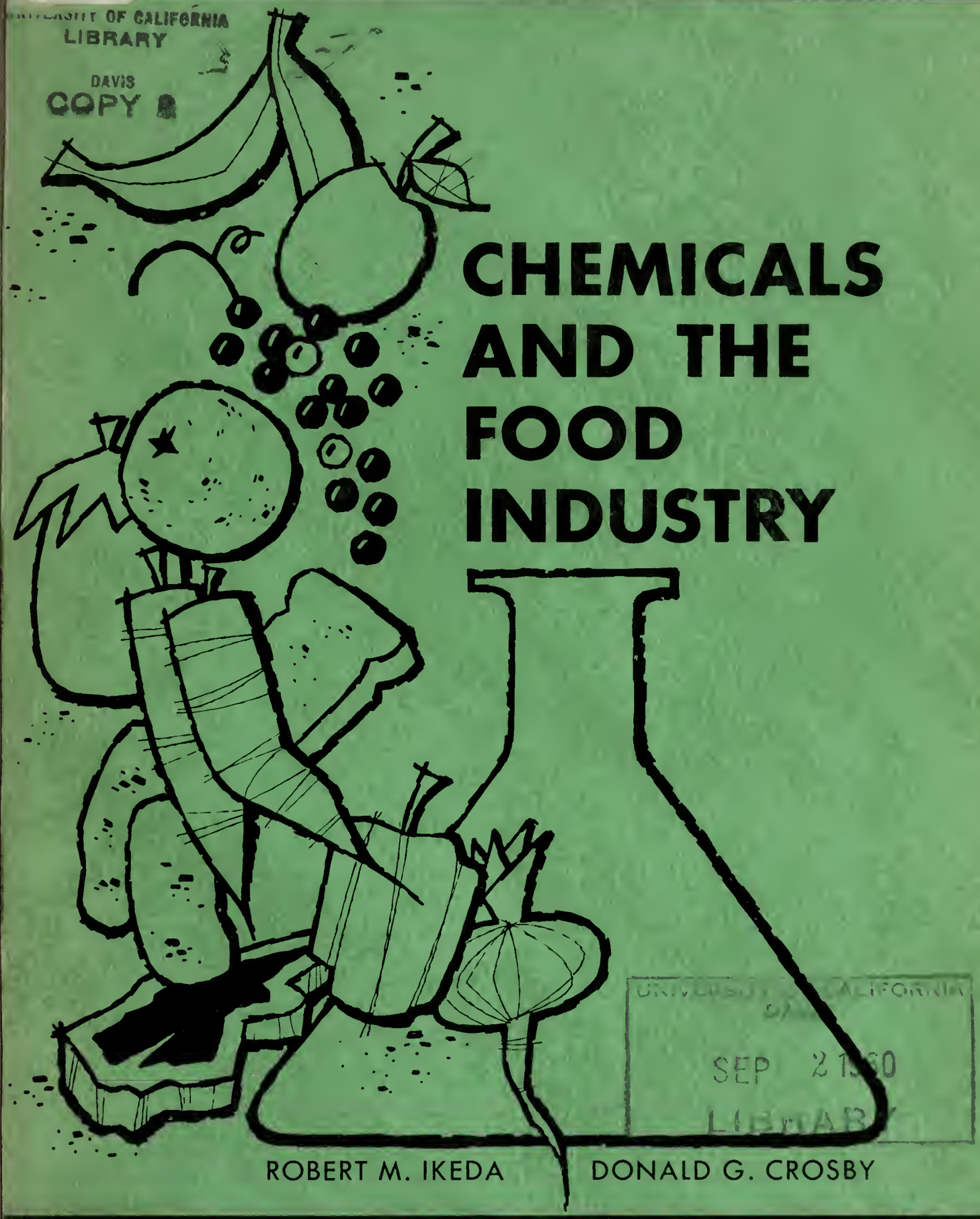
S
39
E92
no.26
c.2

Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

UNIVERSITY OF CALIFORNIA
LIBRARY
DAVIS
COPY



CHEMICALS AND THE FOOD INDUSTRY

UNIVERSITY OF CALIFORNIA
SEP 21 60
LIBRARY

ROBERT M. IKEDA DONALD G. CROSBY

CALIFORNIA AGRICULTURAL
Experiment Station
Extension Service

MANUAL 26
Price $1.00

LIBRARY
UNIVERSITY OF CALIFORNIA
DAVIS

JUNE
1960

CHEMICALS AND THE FOOD INDUSTRY

ROBERT M. IKEDA*
Department of Food Science and Technology,
University of California, Davis.

DONALD G. CROSBY
Research Department, Union Carbide Chemicals
Company, Division of Union Carbide Corporation,
South Charleston, West Virginia.

*Present address: Fruit and Vegetable Chemical Laboratory, U.S.D.A., Pasadena, California.

UNIVERSITY OF CALIFORNIA DIVISION OF AGRICULTURAL SCIENCES
Agricultural Experiment Station—Extension Service

LIBRARY
UNIVERSITY OF CALIFORNIA
DAVIS

FOREWORD

There is a great deal of confusion and misinformation being disseminated about the use of chemicals by the food industry, not only among lay people but also even among food scientists and technologists. Many people believe that the use of chemicals in food is inherently harmful and must be avoided at all costs. They are either not aware or do not stop to realize that foods themselves are mixtures of chemicals. Many, perhaps most of the lay public, do not appreciate that modern chemistry is a most useful tool in the solution of food production, processing and marketing problems; in certain cases the use of a chemical may be the only sure and safe way to solve a food problem. Because of these facts the authors of this publication have sought to present the "facts of the case". The main objective is to discuss the legitimate use of chemicals in the processing, manufacture, storage, and distribution of food. Their use in producing foods has been left to others to discuss.

In the main part of this manual the general nature of the U. S. food industry is treated. Key statistics relating to trends in production-consumption patterns are presented with indications for the future. Next some of the key technical problems of the industry are listed and discussed. Examples are provided to show how chemicals are being or might be used in the solution of these problems.

Another section of the manual deals with the current use of chemicals by the food industry. The data given were obtained both by a survey of the food and chemical literature as well as by means of direct contacts made by one of the authors. These are enlightening facts and show the great extent to which chemicals have been found useful in solving food processing and marketing problems.

In a final section there is listed chemicals now permitted in foods by federal regulatory agencies: U. S. Food and Drug Administration, Agricultural Research Service (U. S. Department of Agriculture) and the Agricultural Marketing Service (U. S. Department of Agriculture). It should be noted that these lists are complete and accurate only as of the date the manual went to press.

Applications for the use of new chemicals in food and reappraisal of the safety of already-approved chemicals are under continuous review by regulatory officials. Up-to-date information may best be secured by communicating directly with the federal agencies concerned.

E. M. Mrak
G. F. Stewart
University of California, Davis

CONTENTS

Part I.

Introduction 1
A. Food Consumption in the United States 1
B. Relationship of Chemicals to the Food Industry 9
C. Development of Chemicals for Food Use 12

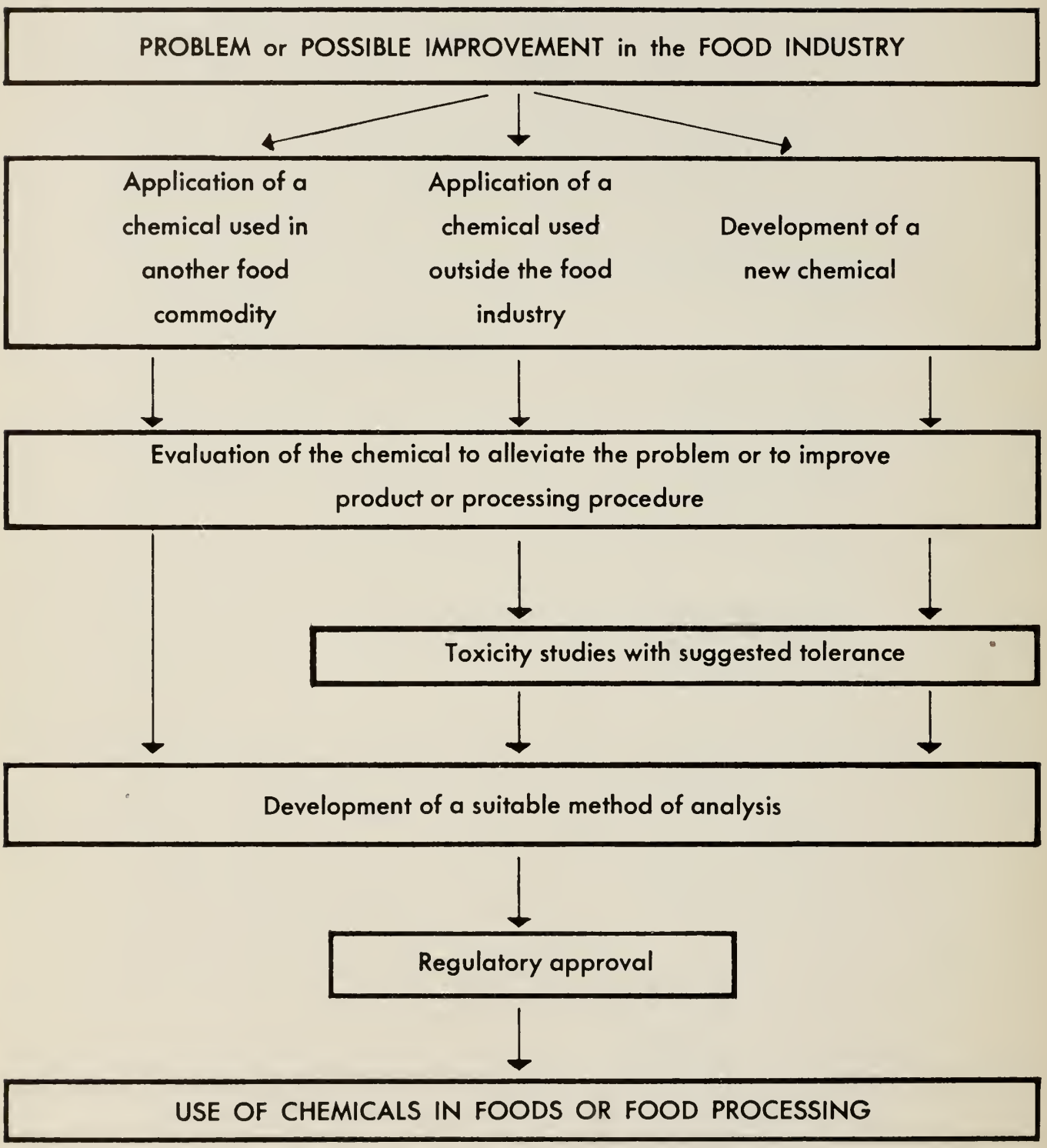
Part II.

Problems of the Food Industry 14
A. General Food Problems 14
B. Meat 16
C. Poultry 22
D. Fish and Fish Products 25
E. Dairy Products 30
F. Eggs 35
G. Fats and Oils 37
H. Fruits and Vegetables 43
I. Cereals and Cereal Products 52
J. Wine 65
K. Beer 70
L. Coffee and Tea 73
M. Cocoa and Chocolate 77
N. Sugar and Honey 82
O. Spices 84
P. Animal Feed 87

Pare III.

Chemicals Used by the Food Industry 93
Preservatives 94
Nutritional Supplements 96
Coloring Agents 97
Flavoring Agents 99
Agents to Improve Functional Properties 103
Processing Aids 105
Moisture Content Controls 107
Controls for Acidity and Alkalinity 108
Controls for Physiological Activity 109
Other Agents 109

Official Lists of Approved Chemicals 110


PROBLEM or POSSIBLE IMPROVEMENT in the FOOD INDUSTRY
Application of a chemical used in another food commodity
Application of a chemical used outside the food industry
Development of a new chemical
Evaluation of the chemical to alleviate the problem or to improve product or processing procedure
Toxicity studies with suggested tolerance
Development of a suitable method of analysis
Regulatory approval
USE OF CHEMICALS IN FOODS OR FOOD PROCESSING

PART I—INTRODUCTION

A

Food Consumption in The United States

According to statistics compiled by the United States Department of Agriculture (1), the American public spent some 67 billion dollars for food in 1957, out of a disposable personal income of more than 305 billion dollars. Clearly, a greater proportion of the average family's income goes for food than for any other single category on its budget, and there are strong indications that even this markedly large apportionment is consistently on the increase.

Between 1950 and 1957, *per capita* food expenditures increased 24 per cent, while the retail food price index increased 24 per cent, while the retail food price index increased by only 12 per cent. Several factors can account for the increased food expenditures: The *per capita* disposable income increased 39 per cent during this period, and with this increase came a shift in food habits from the consumption of low-cost commodities, such as cereal products and potatoes, to more expensive items, such as meat and poultry. Furthermore, there was a new willingness evinced to pay higher prices for store convenience, attractive packaging and display, quality, and service. The highly planned supermarket was replacing the randomly organized corner grocery.

Table 1 shows the percentage of the food dollar that was spent on the various food commodities from 1947–49, the period commonly referred to in establishing agricultural indices. Such indices are readily available, and can be used to extend the information in Table 1 to any given year.

It is indicative of the increased importance placed on them in the diet that more than one-half of the food expenditures were made for meat, poultry, and the dairy products, and it is interesting to note that there was a pronounced rise in civilian buying of these foods even during wartime rationing (Figure 1). While the consumption of most vegetables and fruits has remained remarkably constant for many years, there has been a dramatic increase in the use of citrus fruits and tomatoes. The consumption of fats and sugars also has been fairly constant, with the exception of the period of World War II rationing (Figures 2, 3). And Americans are now drinking more coffee, tea, and cocoa than ever before (Figure 4).

During the past few years, a large number of convenience items, such as precooked frozen foods, cake mixes, etc., have appeared on the market. Although there are no statistical data on these items, it is reasonable to assume their widening popularity (2). (It is possible, incidentally, that the continued decline in overall use of potatoes may be retard-

Table 1. Food Expenditures in the United States (1947–49).

Commodity	Per capita consumption in 1947–49	Per cent of food dollar
	pounds	per cent
Meat, Fish, and Poultry		
Meat		
Beef	51.0	9.8
Veal	8.8	1.6
Lamb and mutton	4.2	.8
Pork (including bacon and salt side)	62.7	10.0
Offals	10.4	1.9
Total Meat	.....	24.1
Fish		
Fresh (edible weight)	5.9	1.3
Canned	3.8	.9
Cured	0.6	.1
Total Fish	.....	2.3
Poultry		
Chicken (dressed weight)	23.7	4.0
Turkey (dressed weight)	4.0	.9
Total Poultry	.....	4.9
Total Meat, Fish, and Poultry	.....	31.3
Eggs	46.7	6.3
Dairy Products		
Fluid Milk	299.0	8.7
Fluid cream	9.6	1.2
Cheese	6.9	1.3
Condensed and evaporated milk	19.8	.8
Ice cream (actual weight)	18.5	3.0
Buttermilk (natural and cultured)	38.9	.7
Fluid skim milk	12.8	.2
Milk in chocolate drinks	6.5	.2
Nonfat dry milk solids	3.1	.2
Cottage cheese	2.9	.2
Total Dairy Products, excluding butter	.....	16.5
Fats and Oils		
Butter	10.5	2.5
Lard	12.2	1.0
Margarine	5.5	.7
Shortening	9.5	1.1
Other edible oils	7.2	1.2
Total Fats and Oils, including butter	.....	6.5

Table 1—(Continued)

Commodity	Per capita consumption in 1947–49	Per cent of food dollar
Fruits	pounds	per cent
Fresh		
Oranges and tangerines	35.3	1.0
Grapefruit	11.6	.3
Lemons and limes	4.3	.2
Apples	27.7	1.0
Bananas	18.9	.9
Grapes	5.3	.2
Peaches	11.1	.4
Pears	4.9	.2
Cantaloupe	6.5	.1
Watermelons	14.3	.1
Other	6.2	.3
Home garden melons	12.5	.2
Total Fresh Fruits	.....	4.9
Canned		
Apples and applesauce	1.8	.1
Apricots	1.0	.1
Peaches	4.5	.2
Pears	1.3	.1
Pineapples	2.8	.2
Salad and Cocktail	2.1	.1
Other	4.6	.3
Total Canned	.....	1.1
Canned Juices		
Grapefruit	3.3	.1
Orange	4.3	.1
Blend	2.1	.1
Other	6.3	.3
Total Canned Juices	.....	.6
Frozen Fruits and Juices		
Concentrated juices	.4	.1
Fruits	2.9	.3
Total Frozen	.....	.4
Dried Fruits		
Prunes	1.2	.1
Raisins	1.8	.1
Other	1.2	.1
Total Dried	.....	.3
Total Fruits	.....	7.3

Table 1—(Continued)

Commodity	Per capita consumption in 1947–49	Per cent of food dollar
	pounds	per cent
Vegetables		
Fresh		
Beans, snap	4.1	0.3
Cabbage	13.8	.3
Carrots	8.1	.3
Celery	7.0	.4
Corn	6.8	.1
Lettuce	14.0	.6
Onions	10.2	.3
Spinach	1.4	.1
Tomatoes	10.9	.4
Other	29.6	1.5
Home garden output	90.6	3.7
Total Fresh	.....	8.0
Canned		
Beans, snap	2.8	.1
Beets	1.1	*
Corn	5.2	.3
Peas	5.6	.2
Pickles, mixed	3.3	.3
Spinach	1.1	.1
Tomatoes, whole	4.3	.2
Tomato catsup and chili sauce	2.5	.2
Tomato paste, pulp, and puree	3.3	.2
Vegetable juices	4.1	.1
Other	5.3	.4
Total Canned	.....	2.1
Other Processed Products		
Canned baby foods	3.2	.3
Frozen vegetables	2.9	.3
Canned soups	9.3	.7
Total Other Processed	.....	1.3
Total Vegetables	.....	11.4
Potatoes and Sweet Potatoes		
Potatoes	104.5	1.7
Sweet potatoes	10.6	.3
Home garden output	2.3	.1
Total	.....	2.1

* Less than 0.05 per cent.

Table 1—(Continued)

Commodity	Per capita consumption in 1947–49	Per cent of food dollar
	pounds	per cent
Beans, Peas, and Nuts		
Dry edible beans	6.6	.6
Dry field peas	.6	*
Peanuts	4.4	.6
Tree nuts (including coconut)	2.4	.8
Home garden dry beans and peas	2.0	.2
Total	.....	2.2
Cereal Products		
White and whole wheat flour	129.0	5.8
Semolina flour	6.2	.4
Wheat cereal	3.1	.2
Rye flour	1.4	.1
Corn meal	13.4	.3
Corn cereal	1.5	.1
Oatmeal and other oat food products	2.9	.1
Rice	4.8	.3
Total	.....	7.3
Sugars and Syrups		
Sugars (excluding duplication)†	90.4	5.7
Syrups (excluding refiners' and honey)	12.9	.5
Total	.....	6.2
Candy	.....	.....
Beverages		
Coffee	18.0	2.4
Tea	.6	.3
Cocoa	4.0	.2
	.....	
Total	.....	2.9
Soda	....	....
Beer	....	....
Wine	....	....
Condiments		
Vinegar	....	....
Mustard	....	....
Salt	....	....
Pepper	....	....
All Foods in Index	....	100.0

* Less than 0.05 per cent.

† Excludes sugar used in frozen and canned fruits and juices, canned vegetables, condensed milk, and ice cream.

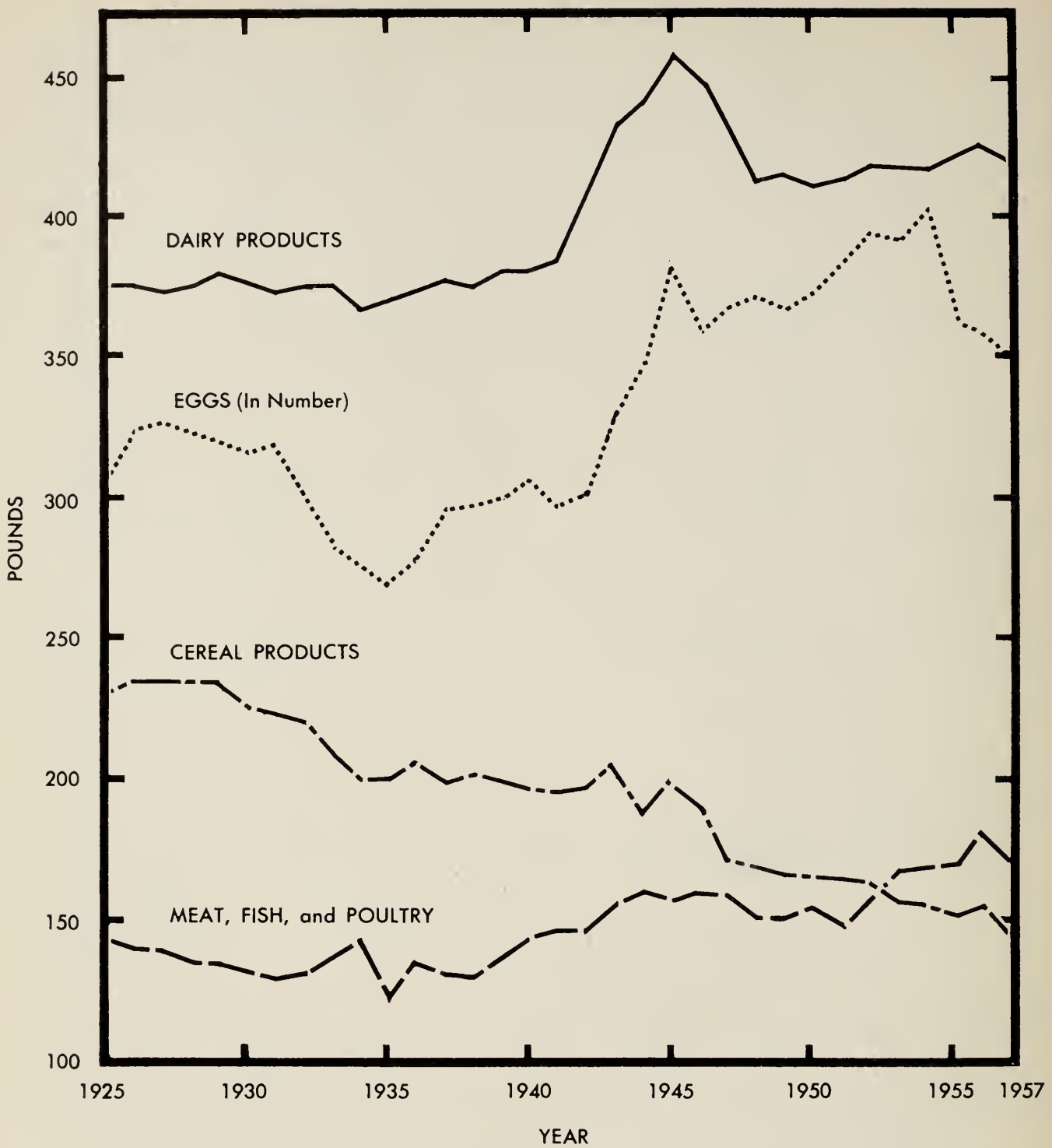


Fig. 1. Approximate per capita U.S. food consumption patterns, major food groups.

ed somewhat by the recent introduction of packaged, processed products, such as frozen mashed potatoes.)

More and more of the drudgery of food preparation is being borne by the food processor, thereby relieving the housewife of this burden and freeing her time for other activities. But with processing ever more in the food picture, the problems of preparation, storage, and distribution are multiplied, and to meet this challenge, processors are inevitably employing scientific methods to make their products easier to use, tastier, less perishable, and more nutritious. Chemicals already have found their place in helping meet these needs, and their use is certain to increase.

Fig. 2. Approximate per capita U.S. food consumption patterns, major food groups.

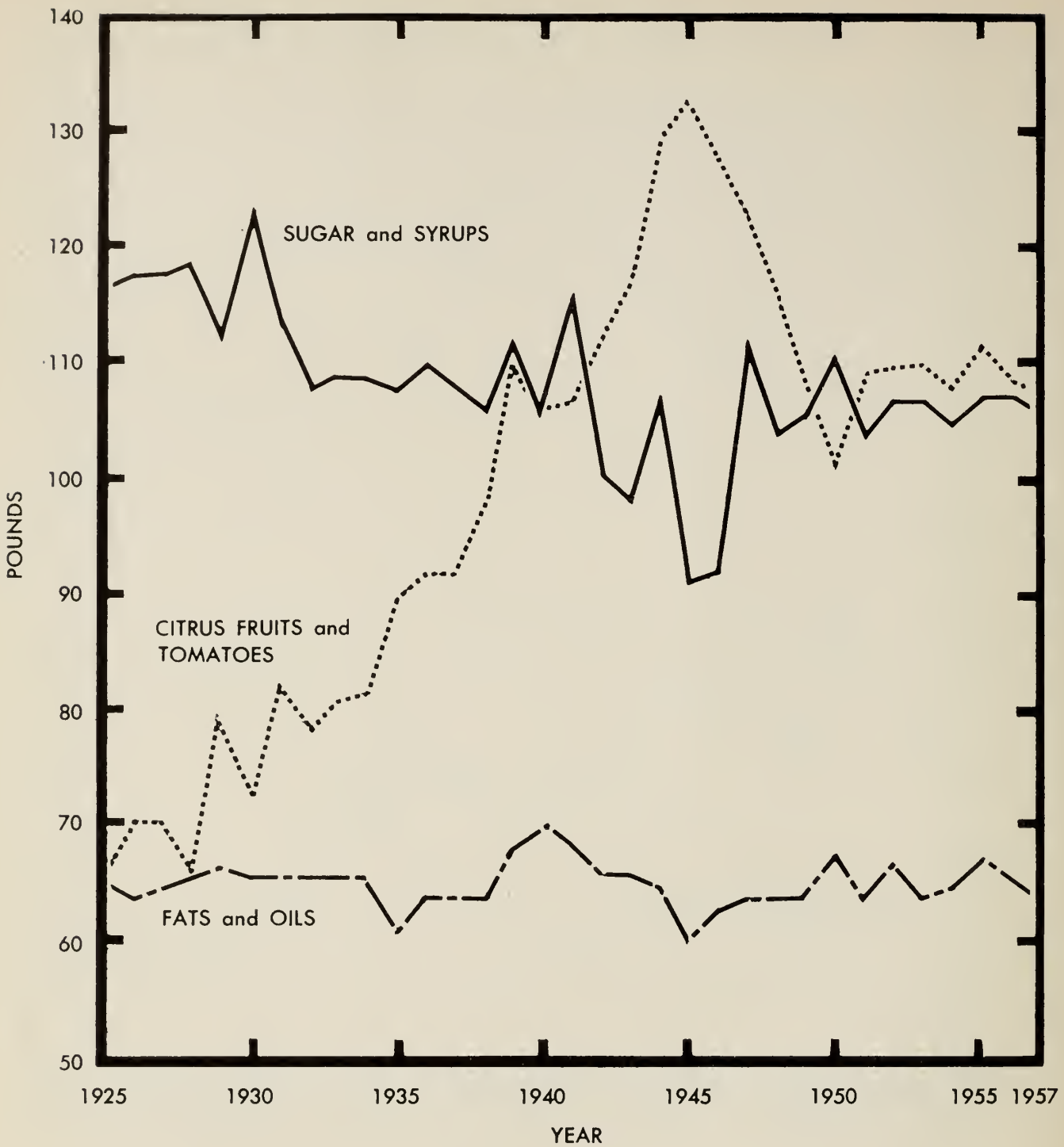


Fig. 3. Approximate per capita U.S. food consumption patterns, major food groups.

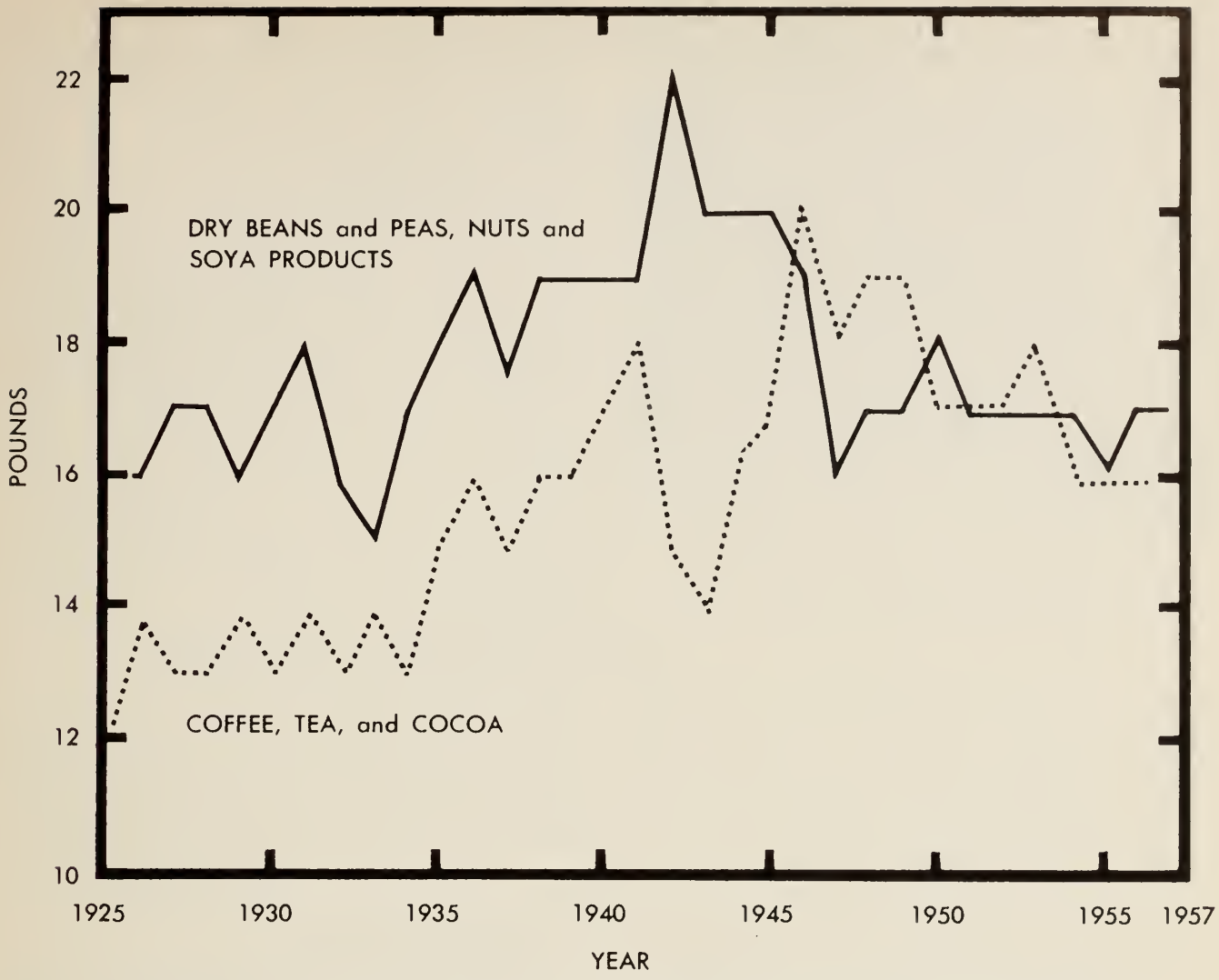


Fig. 4. Approximate per capita U.S. food consumption patterns, major food groups.

B

Relationship of Chemicals to the Food Industry

The definition of the term "food industry" is an arbitrary one, since the movement of food from the farm to the consumer's home involves so many different activities. For present purposes, we will assume that any operation which involves manufacture, treatment, processing, or storage of commercial food items, between harvest or slaughter, and wholesale distribution, is carried out by a "food industry."

In 1955, the 28 most important food manufacturers reported sales totaling $5,813,000,000, an increase of more than 83 per cent over their sales in 1945. In 1957, 1,688,228 workers were employed by about 40,000 separate food manufacturers; Table 2 indicates the dispersal of these employees throughout the industry.

In 1947, the food industries were the nation's largest consumers of chemicals (including fats and oils), making purchases amounting to approximately 1.2 billion dollars, or 8.6 per cent of the total chemicals' sales. Table 3 shows the con-

Table 2. Workers Employed by Food Manufacturers (1957).

Industry	Number employed
Meat	313,106
Dairy	296,751
Canned and frozen food	213,319
Grain products	107,375
Bakery products	303,746
Sugar	28,300
Candy, etc.	79,985
Beverages	202,363
Miscellaneous food	143,283
Total	1,688,228

tribution of each type of chemical to this total.

Unfortunately, more recent information on such chemical consumption is incomplete. Government data presented here were not released until 1955, which indicates the difficulty with which reliable statistics on the subject are accumulated. More extensive and timely data may be available in the future through a regular "census of manufacturers" (4).

The uses to which these chemicals are currently being put by food manufacturers may be considered in several categories:

1. Preservatives

The three general types of preservative problems for which chemicals are used are microbiological spoilage, chemical deterioration, and insect infestation. Common examples of compounds employed for these purposes are salt to preserve fish, sulfur dioxide to maintain acceptable color in dried fruit, and methyl bromide to prevent insect infestation of cereals and other foods.

2. Nutritional supplements

The use of additives such as vitamins, minerals, and amino acids, has improved general nutrition in this country. An example is the supplementation of flour with Vitamin B_1, riboflavin, and iron.

3. Coloring agents

Food color may be intensified, modified or stabilized by the use of natural coloring materials, certified food dyes, or derived colors. Compounds are now

Table 3. Purchases of Chemicals by Food and Kindred

	Meat and poultry	Dairy products	Food preservation	Grain products	Bakery products
Inorganic chemicals	1.3	1.7	1.0	4.5	0.9
Organic chemicals	0.2	0.3	7.3	0.4	0.2
Plastics	0.0	0.0	0.0	0.0	14.5
Synthetic rubber	0.0	0.0	0.0	0.0	0.0
Synthetic fibers	17.7	0.0	0.0	0.0	0.0
Explosives	0.0	0.0	0.0	0.0	0.0
Drugs—medicines	0.2	0.0	0.0	33.3	0.0
Soap, glycerol, etc.	0.0	0.0	0.0	0.0	0.0
Paint	1.0	0.5	0.5	0.5	0.0
Gum and wood chemicals	0.0	0.0	0.0	0.3	0.0
Fertilizers	0.0	0.0	0.0	0.0	0.0
Vegetable oils	19.9	0.0	54.5	38.5	19.1
Animal oils	50.0	0.0	0.0	9.7	0.0
Miscellaneous	16.5	17.8	3.5	3.1	5.2
Total	106.8	20.3	66.8	90.3	39.9

added to butter for uniform color-maintenance throughout the year, and the red color in cured meat products, such as ham and bacon, is due to the sodium nitrite used in the curing process.

4. Flavoring agents

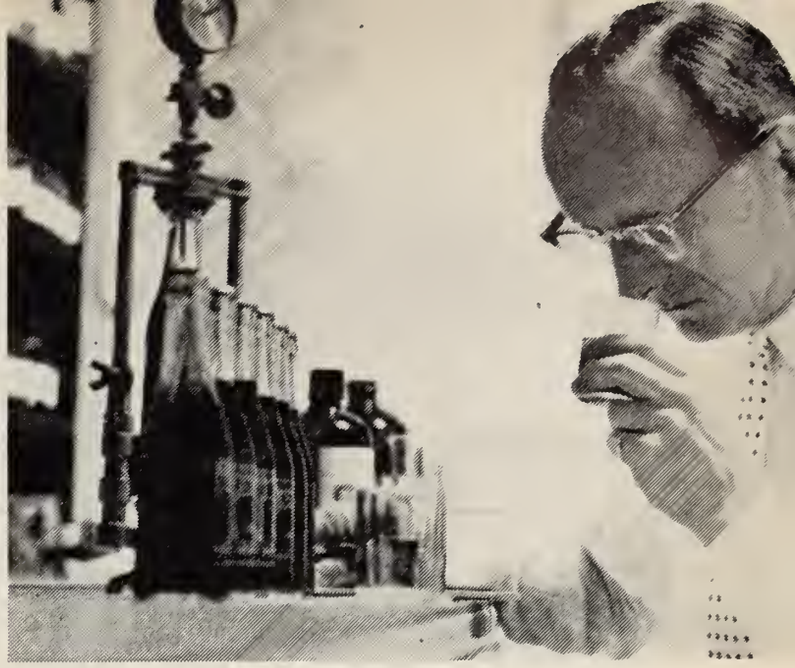
Both synthetic and natural flavors are extensively added to soft drinks, and sodium glutamate is used to impart a meat flavor to canned vegetables and soup.

5. Agents to improve functional properties

Additives used for this purpose act as thickening, firming, and maturing agents, or may affect the colloidal properties of foods, such as gelling, emulsifying, foaming, and suspension. Calcium salts firm the texture of whole canned tomatoes, and chlorine dioxide is used as a maturing agent in flour.

6. Processing aids

These include sanitizing agents, chemicals to remove extraneous or other materials, metal binding compounds, antifoam agents, and substances added to prevent fermentation. Detergents are used to facilitate the removal of dirt and insects; silicones act at antifoam agents in wine fermentation; and citric acid is used as a binding compound to reduce the action of metals in oxidative rancidity.



Final evaluation of flavor depends on the educated palate of an expert. (Photo courtesy International Flavors & Fragrances, Inc.)

7. Moisture content controls

Chemicals are employed to increase or decrease moisture levels in a variety of commodities; glycerine is used in marshmallows as a humectant to retain soft texture; and calcium silicate is added to table salt as an anticaking agent.

8. Controls of acidity and alkalinity

Various acids, alkalies, and salts are added to food to obtain a desired pH; phosphoric acid is used in soft drinks; and salts, such as sodium citrate, are added to fruit jellies.

9. Controls for physiological activity

The chemicals in this category are applied to fresh produce, to act as ripening or antimetabolic agents; ethylene hastens ripening in bananas; and maleic hydrazide prevents sprouting of potatoes.

A list of chemicals and their uses for the purposes stated above, appears in Part III.

Industries (1947) (4).

Sugar	Alcoholic beverages	Miscellaneous	Total
2.5	0.5	12.8	25.2
0.0	16.5	14.6	39.5
0.0	0.0	10.4	24.9
0.0	0.0	2.2	2.2
0.0	1.5	0.7	19.9
0.0	0.0	0.0	0.0
0.0	0.0	5.5	39.0
0.0	4.5	3.4	7.9
0.0	0.0	0.5	3.0
0.0	0.0	0.5	0.8
0.0	0.0	0.0	0.0
0.0	0.0	718.7	850.7
0.0	0.0	18.4	78.1
1.8	0.2	53.2	101.3
4.3	23.2	840.9	1,192.5

Development of Chemicals for Food Use

The food industry needs the cooperation of the chemical industry in learning how best to approach the problem of using chemicals in its products and processes, and how to decide which new compounds hold the greatest promise. A pertinent statement was made in this respect by Sir Frank Engledow in his address to the British Food Manufacturing Industries Association (5). He said, "The food industry should beware of the danger of waiting for the 'creative' sciences to hand over their discoveries and developments. They will not and cannot go far out of their way for food manufacture unless we can tell them what we want and give them initial ideas for wholly new developments."

In developing chemicals to be applied to foods, a number of factors must be considered. Obviously, the chemicals must facilitate production or improve quality without concealing inferiority or minimizing the need for good manufacturing practices. In the early days of modern food manufacture, the application of chemicals to food products and processes was so abused that manufacturers and customers alike came to associate the term "chemical additive" with inferior or undesirable food quality. That some measure of this feeling about additives persists is best evidenced by the fact that virtually no chemical additives are used directly in milk today, even where their use would frequently constitute an improvement.

The nutritive value and organoleptic properties of the food products must not be impaired by the additive. Often, in investigations of the development of food additives, the *full* effect of the additive is ignored. Its effect on texture, flavor, and color must be considered not only in the application, but also after storage and shipment through regular marketing channels. It is a basic fact of food marketing that physically unacceptable products will not sell.

The safety of the additive and of its decomposition under conditions of common usage, must be established beyond any doubt (6, 7, 8). Regulatory authority has been retained by the Federal Government (U. S. Food and Drug Administration), state boards, and various agencies of local government. Such control is of universal benefit, and several groups, notably the Food Protection Committee of the National Research Council, are engaged in establishing sound scientific bases on which to give approval to additive substances.

In recent years, the public and its representatives have shown increasing "interest" in health problems arising from the use of chemicals in food products. Passage of the "Pesticide Amendment," in 1954, and the "Food Additives Amendment," in 1958 (to the Food, Drug and Cosmetical Act, 1938), provided a much-needed definition of the positions held by chemical manufacturers, food processors, and Government, regarding food chemicals. Further information on the subject is to be found in a good review by Frey (12), which contains an extensive bibliography. Much

further clarification and interpretation of the food additives legislation will undoubtedly be provided in the future; it is certain that the importance of chemicals in the food industry is only beginning to be realized.

LITERATURE CITED

1. United States Department of Agriculture, Bureau of Agricultural Economics.
1953. Consumption of food in the United States 1909–1952. Agriculture Handbook No. 62 (Sept.; Suppl. July 1958).

2. Clark, F.
1956. Family spending for food. Cereal Sci. Today, 1, 155.

3. Harrel, C. G., and B. M. Dirks
1955. Cereal and cereal products. In Handbook of Food and Agriculture, ed. by F. C. Blanck. Reinhold Publishing Corporation, New York.

4. United States Department of Commerce
1949. Census of manufacturers. Series NC61T-1, March.

5. Engledow, Sir Frank
1956. Food manufacture should be more scientific. Food Manuf., 31, (8), 330.

6. Lehman, A. J., W. I. Patterson, B. Davidow, E. C. Hagan, G. Woodward, E. P. Laug, J. P. Frawley, O. G. Fitzhugh, A. R. Bourke, J. H. Draize, A. A. Nelson, and B. J. Vos
1955. Procedures for the appraisal of the toxicity of chemicals in food, drugs, and cosmetics. Food, Drug, Cosmetic Law Jour., 10, 679.

7. Food Protection Committee, Food and Nutrition Board
1952. Safe use of chemical additives in foods. National Research Council, Washington, D.C., Dec.

8. Food Protection Committee, Food and Nutrition Board
1954. Principles and procedures for evaluating the safety of intentional chemical additives in foods. National Research Council, Washington, D.C., Nov.

9. Hazelton, L. W.
1957. Biological evaluation of agricultural and food chemicals. Jour. Agr. Food Chem. 5, 336.

10. Mickelsen, Olaf
1957. Chemicals and food processing. Nutrition Rev. 15, 129.

11. United States Department of Commerce, Bureau of Labor Statistics
1959. Employment and earnings. Washington, D.C., Feb.

12. Frey, C. N.
1955. Chemicals in foods. In Handbook of Food and Agriculture, ed. by F. C. Blanck, Reinhold Publishing Corporation, New York.

13. Aser, B. L.
1958. The food industry in a changing world. Food Tech. 12, 493.

PART II—PROBLEMS OF THE FOOD INDUSTRY

General Food Problems

1. The control of microbial spoilage is the most critical problem facing the food industry today. In considering ways to meet this problem, it should be noted that in most instances absolute sterility of food is not a necessary condition for its preservation. Although the development of a process that would produce absolute sterility would be of value, many kinds of food deterioration are caused by the growth of a single species of organism, in which case selective control of that organism would solve the problem. Inactivation of strict aerobes, for instance, would be unnecessary in sealed containers; attention needs to be turned only to the inactivation of those organisms which grow and lead to deterioration under the given environmental conditions.

2. Another major difficulty lies in finding a bactericide or bacteriostatic agent that is nontoxic or relatively nontoxic to man. Thus, it would be highly desirable to develop a compound that would destroy the microorganisms and then decompose to nontoxic products, either on cooking or after application. Aureomycin, hydrogen peroxide, propylene oxide, and peracetic acid are such compounds which have been used commercially or experimentally in foods.

3. In the production of commodities such as wine, beer, pickles, and cheese, the development of certain specific organisms is desirable. It would be of value to the producers to have an agent that would allow the development of the desirable organisms, but no others. A knowledge of the nutritional requirements of both desirable and undesirable species might lead to the development of antimetabolites which would inhibit the growth of those which are unbeneficial. These antimetabolites might be structural analogs of the vitamins and amino acids required for the growth of the spoilage organisms. It should be realized, however, that such an approach might not provide a permanent solution to the problem, because of the possibility of the spontaneous mutation and adaptation of the organisms involved.

4. In nonacid foods, such as canned vegetables, meat, and fish, an excessive amount of heat is required to inactivate bacterial spores. Such heat treatment leads to changes in flavor, texture, and color. To obtain a more acceptable product, it would be helpful to have a safe agent that would inhibit spore germination and thus make it possible to reduce the period of treatment. In addition, an agent which would replace the pasteurization which many of our foods undergo would be of value to the industry. Bac-

teriostatic agents, such as benzoic acid and sorbic acid, are effective in acid media, but no such agent has been discovered which is satisfactory under neutral or alkaline conditions.

5. Although a number of bactericides are presently available for application to fresh fruits and vegetables, there is still no really effective agent which will control microbial spoilage throughout the marketing period.

6. At present, the only practical means of inactivating enzymes which may lead to deteriorative changes in food, is through the application of heat. The delicate flavor of many food items is partially lost by such treatment, however, and a suitable "antienzyme" might help to retain flavor quality. There are many chemicals which are known to inactivate enzymes, but most of these are impractical for food use.

7. Non-enzymatic browning, assumed to be a carbonylamine reaction, is a chemical deterioration which occurs in almost every food commodity, and for which no effective means of control has been found. In some instances, sulfur dioxide is used to retard browning, but this gas imparts an undesirable odor and flavor. In the production of egg solids, browning is inhibited by oxidation of glucose to gluconic acid by the action of the enzyme glucose oxidase, and such an approach may well have application in many other food fields.

8. Lipid oxidation is another important type of chemical deterioration. Although a number of good antioxidants are presently available, not all have been specifically approved in many fat-containing foods. The presence of copper and iron in these foods is known to catalyze oxidation. Citric acid and phosphoric acid are permitted in some foods to reduce the action of these ions, but chemicals more effective than these are needed.

9. The fumigants currently in use are effective against insects when properly applied, but an agent which would *prevent* insect contamination would be valuable; the need for repeated fumigation would thus be eliminated.

10. Because a number of synthetic food dyes have recently been removed from the list of acceptable food additives, new sources of coloring matter are needed.

11. There are as yet no effective thinning agents which would obviate the excessive dilution with water of certain foods which require thinning, although there are some satisfactory thickening agents available.

A look at nature may suggest a rational approach to the development of food additives. There exists a wide range of natural colors, one of which is currently being synthesized for use in food (beta-carotene); perhaps other colors can be made synthetically. There are also many natural antioxidants, natural fungistats which enable plants to resist disease, and some food items which contain natural insect attractants or repellants. These constituents may be quite complex, but the structural features essential to their physiological activity might provide information which would lead to synthesis of less complicated active compounds.

Whenever the use of food additives is considered, the problem of how best to incorporate the agent into the product must be solved. Because of the power of living things to detoxify foreign chemicals, little research has been done on the possibility of distributing additives throughout the food source prior to harvest or slaughter. In experiments making use of the circulatory system of animals to distribute antibiotics or chemicals, it was found that only small percentages of the agents accumulated, although the use of potato leaf sprays containing maleic hydrazide has proved to be successful, and does inhibit the sprouting of potato tubers long after harvest.

Although solutions to many such food problems are known, there are often practical considerations that make the

knowledge difficult to apply. For example, adequate refrigeration would reduce much of the microbial spoilage in fresh fruits and vegetables, but ideal storage conditions seldom are available under the present marketing system. Thus, to minimize loss as these items pass through marketing channels, some simpler and more reliable method of preservation must be sought. Precooked frozen items present a particularly serious potential hazard under improper handling.

The ultimate "problem," of course, is the consumer. His tastes vary from season to season, year to year, and to some extent, geographically from place to place. In general, however, his food must fit his budget, appear attractive, appeal to taste and smell, and be nutritious. Above all, it must "suit his fancy." Any means by which these requirements are served will be of interest and benefit to the food industry.

The food industry is constantly faced with the dual problem of meeting consumer demands and at the same time realizing a reasonable profit. Some of the major problems which beset producers in their endeavor to accomplish this end, are presented in the following pages.

LITERATURE CITED

A-1. Blanck, F. C.
1955. Handbook of Food and Agriculture. Reinhold Publishing Corporation, New York.

A-2. Jacobs, M. B.
1951. The Chemistry and Technology of Food and Food Products, second edition. Interscience Publishers, Inc., New York.

A-3. United States Department of Agriculture, Bureau of Agricultural Economics
1953. Consumption of food in the U.S. 1909–1952. Agriculture Handbook No. 62 (Sept.; Suppl. Oct. 1955, July 1958).

Meat

1. Introduction

During the 1947–49 period, 24 cents (and in 1957, 25 cents) of every food dollar was spent for meat, the most expensive item on the food budget. Statistics on the consumption of meat, fish, and poultry during this period show that these foods provided 12.6 per cent of the energy, 29.2 per cent of the protein, and 22 per cent of the fat in the American diet. They also provided 24.1 per cent of the iron, 22.6 per cent of the thiamine, 16.1 per cent of the riboflavin, and 41.9 per cent of the niacin (B-1).

The gradual rise in meat consumption has been indicated previously. In 1957, meat production totaled 26.9 billion pounds in the United States, and the scale of meat processing operations can be gauged by the fact that in 1955 the meat industry's two major companies (Swift and Armour) were rated among the top ten corporations in the United States. Figure B-1 shows the *per capita* consumption of the various animal meats (B-1). It can be seen from this figure that during the last several years beef consumption has exceeded that of pork, while the

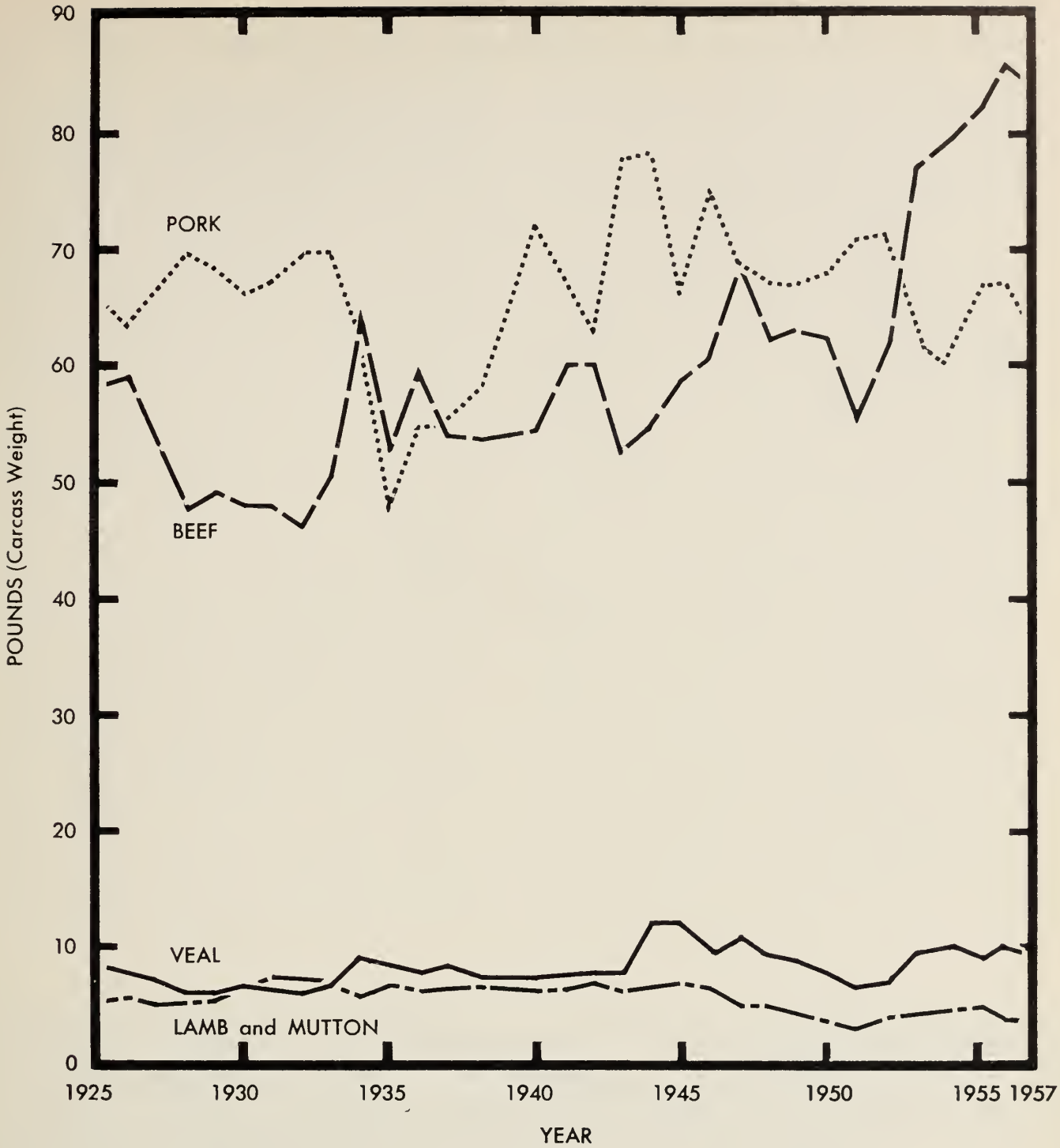


Fig. B-1. U.S. per capita consumption of meat (primary distribution weight).

use of veal, lamb, and mutton has remained almost constant.

The fundamental steps (bleeding, and removal of stomach, intestines, hide, hoofs, and horns) involved in the processing of animals have remained unchanged for many years, although with the industrialization and growth of the meat industry, refinements in processing and mechanical handling have been developed. Actually, there is a relatively limited amount of processing necessary for fresh meat. The animal is slaughtered and cooled [the slaughtering procedure varies with the type of animal (B-3. B-4)], and most of the carcasses are moved out of the processing plant at this point. The amount of aging depends on the purchasers' needs. The highest grade of beef, primarily for the restaurant trade, may be aged for as much as 4 to 6 weeks, but with the recent trend toward

prepackaging, most of the meat is sold within 1 to 2 weeks after slaughter. It has been predicted that within 5 years, 30 to 50 per cent of the meat sold will be prepackaged and frozen (B-5).

2. Commodity problems

a. Fresh meat

In his 1955 article in *Advances in Food Research,* Ayres (B-6) discusses slaughtering methods in relation to microbiological contamination. He suggests that a study be made of the efficacy of detergents and sanitizing agents in removing filth and microorganisms from animals both prior to and during slaughtering operations in order to reduce microbial contamination.

After dressing, carcasses are chilled to firm the flesh, minimize shrinkage, delay the growth of undesirable organisms, and retard chemical deterioration. The principal types of microbial spoilage that can occur in refrigerated fresh meat are off-odor and slime, deep spoilage, and mold discoloration. Mold is no longer a major problem since meat is seldom aged very long.

A number of investigations have been conducted on the use of antibiotics to delay microbiological spoilage in meat (B-7, B-8, B-9, B-10, B-11). Weiser and co-workers (B-12) infused a carcass with antibiotics through the circulatory system of the animal after it was bled, and showed that this method reduced deep spoilage in the meat. Such use of antibiotics by meat producers is now permitted in some countries, but not in the United States; however, Burton (B-13) has predicted that it will be used here in the near future. Perhaps there are other chemicals which could also be employed to control the growth of spoilage organisms.

Future research on chemical control of microorganisms should take into consideration the extensive effort which has been devoted to the preservation of meats by radiation. The present difficulty with this procedure is that off-odors develop when sterilizing dosages are used.

During the cooling and aging of meat, packing house operations are confronted with the problem of shrinkage (loss in weight). The weight lost amounts to as

Aging rooms of a large meat warehouse. (Safeway News photo.)

much as 2.5 per cent, even under optimum conditions. Considering that approximately 25 billion pounds of meat is marketed annually, shrinkage can be very expensive, and a method for reducing this loss would be of vital interest to meat packers. A recent publication suggested as a solution to this problem the use of a coating agent during aging (B-14). However, more experimental work needs to be done before this procedure can come into general commercial use.

Although tenderness in meat is highly desirable and a considerable amount of research has been done on the factors which contribute to tenderness, no commercially satisfactory method has been evolved for insuring this quality. Enzyme preparations which can be applied before cooking are widely available, but for full effectiveness the tenderizer must be physically incorporated with the meat, and this is a difficult and time-consuming process (B-16).

It has been known for a long time that aging tenderizes meat (B-15), and this has been attributed to the action of proteolytic enzymes. To speed aging, higher storage temperatures (65 to 68°F. for 48 hours) may be used; the concurrent growth of microorganisms may be retarded by use of ultraviolet irradiation. Further investigations should be conducted on high-temperature aging, in combination with infusion of the carcass with antibiotics. Also it has been shown that tenderness is related to the presence of certain ions in the meat "juice" (B-17, B-18). This factor deserves further investigation.

Color is a most important factor in meat quality. The desirable red color deteriorates rapidly to an unappetizing gray. This is especially true of prepackaged fresh meat. Actually, there are several reasons for the loss of color: Oxygen, light, dehydration, and microbial action can all produce color changes (B-19). Coleman and Steffen (B-20) have patented the use of the addition of niacin (nicotinic acid) for the retention of a uniform bright-red color in fresh meat. The addition of niacin is not presently permitted under Federal regulation, but it is used in some meats that are not transported in interstate commerce. Ascorbic acid (Vitamin C) has also been suggested as an additive for maintaining proper color; Watts and Lehmann (B-21) state that 0.02 per cent of ascorbic acid is effective in maintaining color.

The prepackaging of fresh meat has led to the problem of "weepage," the excessive loss of liquid from the meat. This difficulty also arises in pork through the development of "soft muscle," which causes leakage, and for which there is no remedy at present. It would be most helpful if a suitable chemical "weepage"-deterrent could be developed.

"Dark-cutting" beef, especially young beef carcasses, has been a problem of long standing to the meat industry. It may appear throughout a meat cut, or it may occur in only a portion of the cut, resulting in a two-toned coloration. The dark color has been attributed to the inability of meat pigment to complex with oxygen to give the desirable red color after cutting. The condition appears to be related to stress prior to slaughter although the exact cause is unknown. A solution to this problem might lie in the development of an acceptable additive that would induce the formation of an oxygen-pigment complex, or in the formation of a pigment having the desired red color.

b. Cured meat

The original purpose of curing and smoking meat was to preserve it. Today, however, meat is cured primarily for taste. In fact, many of the mild-cured products cannot be kept long at room temperatures. The ingredients permitted for curing are: salt, sugar, vinegar, and

certain nitrate, nitrite, and phosphate salts.

Nitrate and nitrite are used in processing cured meat to produce the characteristic red color when it is heated. This heat-stable color is due to a complex containing nitric oxide, and a serious limitation is a susceptibility to light, which causes it to change to an unacceptable gray. Ascorbic acid added to the curing mixture is reported to retard fading (B-22). It would be desirable to find a more stable complexing agent for cured meat color which would not break down so readily when exposed to light.

Rancidity is still a problem in bacon. Although a number of antioxidants are available today, it has been found difficult to incorporate them into the bacon.

The growth of molds, yeast, and micrococci can lead to considerable loss during the distribution and marketing of frankfurters. Ogilvy and Ayres (B-23) have shown that the growth of these organisms is retarded by a partial atmosphere of carbon dioxide. The development of an additive that could be applied to the surface of the frankfurter would be more desirable than gas-packing.

c. Frozen meats

The prediction that sales of prepackaged frozen meat will increase was mentioned earlier. Only within the last few years has there been any real effort placed on the sale of these products (B-24, B-25). The freezer life of frozen beef is about one year, but frozen pork products, on the other hand, retain their good quality only about 6 months. A method for extending shelf life is needed.

d. Canned meats

Objections to heat-processed canned meat are the "soft, mushy" texture and "canned meat" flavor. These undesirable changes arise from the prolonged treatment required to obtain sterility. Drastic heat treatments are necessary to inactivate the resistant spores of spoilage and food poisoning organisms. Such processing cannot be applied to all meat products. For example, since a sterilizing heat treatment has an adverse effect on their quality, large canned hams must be pasteurized and kept under refrigeration. A method for reducing the amount of heat required to control the growth of spoilage organisms would be most welcome. The stability of many microbial spores under heat has stimulated investigations on the factors affecting such thermal resistance (B-26), and on factors influencing sporulation and germination (B-27). The feasibility of using chemicals to prevent spore germination or to decrease thermal resistance should be investigated further.

LITERATURE CITED

B-1. United States Department of Agriculture, Bureau of Agricultural Economics
1953. Consumption of food in the United States 1909–1952. Agriculture Handbook No. 62 (Sept.; Suppl. July 1958).

B-2. Anon.
1956. Directory of the 500 largest industrial corporations. Special insert, In Fortune, 54, (1), July.

B-3. Jensen, L. B.
1949. Meat and meat foods. The Ronald Press Co., New York.

B-4. Urbain, W. M.
1951. Meat and meat products. In the Chemistry and Technology of Food and Food Products, ed. by M. B. Jacobs. Interscience Publishers, Incorporated, New York.

B-5. Anon.
1956. Thirty to fifty per cent frozen prepackaged meat in five years. Quick Frozen Foods, 18(6), 117, Jan.

B-6. Ayres, J. C.
1955. Microbiological implications in the handling, slaughtering, and dressing of meat animals. Advances in Food Research, **6**, 109.
B-7. Tarr, H. L. A., J. W. Boyd, and H. M. Bissett, Jr.
1954. Experimental preservation of fish and beef with antibiotics. Jour. Agr. Food Chem. **2**, 372.
B-8. Niven, C. F., Jr., and W. R. Chesbro
1956. Antibiotics and irradiation in meat preservation. Proceedings 8th Conference on Research, Amer. Meat Inst., March.
B-9. Anon.
1956. Antibiotics keep steaks young. Chem. Eng. News **34**, 5392.
B-10. Ingram, M., E. M. Barnes, and J. M. Shewan
1956. Problems in the use of antibiotics for preserving meat and fish. Food Sci. Abs. **28**, 121.
B-11. Goldberg, H. S., H. H. Weiser, and F. E. Deatherage
1953. Studies on meat. IV. Use of antibiotics in preservation of fresh beef. Food Tech. **7**, 165.
B-12. Weiser, H. H., H. S. Goldberg, V. R. Cahill, L. E. Kunkle, and F. E. Deatherage
1953. Observation of fresh meat processed by infusion of antibiotics. Food Tech. **7**, 495.
B-13. Bowman, B.
1955. Cyanamid's Burton sees early retailing of antibiotic meats. Food Field Reporter **23**(24), 36.
B-14. Anon.
1956. New packaging idea for frozen meat. Western Meat Industry **2**(1) 30.
B-15. Paul, P. C., and L. J. Bratzler
1955. Studies on tenderness of beef. II. Varying storage times and conditions. Food Res. **20**, 626.
B-16. Tappel, A. L., D. S. Miyada, C. Sterling, and V. P. Maier
1956. Meat tenderization. II. Factors affecting the tenderization of beef by papain. Food Res. **21**, 375.
B-17. Wierbicki, E, L. E. Kunkle, V. R. Cahill, and F. E. Deatherage
1954. The relation of tenderness to protein alterations during *post-mortem* aging. Food Tech. **8**, 506.
B-18. Suri, B. R., and H. W. Schultz
1956. Chemical and physical changes in isolated beef muscle tenderized by infusion with sodium chloride. Presented at the 16th Annual Meeting of the Institute of Food Technologists, St. Louis, Missouri.
B-19. Watts, B. M.
1954. Oxidative rancidity and discoloration in meat. Advances in Food Research **5**, 1.
B-20. Coleman, H. M., A. H. Steffen, and E. W. Hopkins
1951. Improving the color of animal meat and blood. U. S. Patent 2,541,572.
B-21. Watts, B. M., and B. T. Lehmann
1952. Ascorbic acid and meat color. Food Tech. **6**, 194.
B-22. Brockmann, M. C., and R. E. Morse
1953. Ascorbic acid aids cured meat color. Proc. 5th Conf. on Research, Amer. Meat Inst., March.
B-23. Ogilvy, W. S., and J. C. Ayres
1953. Post-mortem changes in stored meats. V. Effect of carbon dioxide on microbial growth of stored frankfurters, and characteristics of some microorganisms isolated from them. Food Res. **18**, 121.
B-24. Anon.
1956. Swift prepackaged line requires little change. Food Field Reporter, **24**(1), 1.
B-25. Anon.
1956. Armour to launch frozen meat line. Food Field Reporter, **24**(6), 1.
B-26. Sugiyama, H.
1953. Chemical and physical factors affecting the thermal resistance of bacterial spores. In The Quality and Stability of Canned Meats, ed. by R. G. Tisher, J. M. Blair, and M. S. Peterson. Quartermaster Food and Container Inst., Chicago, Illinois.
B-27. Williams, O. B.
1953. Factors causing sporulation and vegetation of spoilage organisms in canned meats. In The Quality and Stability of Canned Meats, ed. by R. G. Tisher, J. M. Blair, and M. S. Peterson. Quartermaster Food and Container Inst., Chicago, Illinois.
B-28. Erdman, A. M., and B. M. Watts
1957. Spectrophotometric determination of color change in cured meat. Jour. Agr. Food Chem. **5**, 453.

C Poultry

1. Introduction

Chicken and turkey, traditionally holiday fare, are now being eaten throughout the year. This trend is apparent from Figure C-1, which illustrates in particular the phenomenal increase in the consumption of chicken (C-1). The use of turkey has increased also, but at a lower rate. By 1957, the average person in this country was eating 25.6 pounds of "ready-to-cook" chicken and almost 6 pounds of "ready-to-cook" turkey per year.

The rise in *per capita* poultry consumption can be primarily attributed to lower cost, better quality, and greater convenience, which advantages accrued to the consumer as the result of lower mortality and improved breeding, feed conversion, and keeping quality, as well as more extensive use of automation during processing.

Although chickens are raised in every part of the country, over 40 per cent of the commercial broiler production is centered in the South Atlantic states. It is not unusual in these areas to find enterprises handling as many as 100,000 birds.

The processing of poultry consists of killing, bleeding, removing feathers, and eviscerating. More detailed information on these procedures can be found in the articles by Pennington (C-2) and by Lineweaver and Klose (C-3).

Most of the processed chickens are sold chilled, while a major part of the turkey production is marketed in the frozen state. Since about 1950, increasing amounts of convenience items such as precooked frozen poultry products (TV dinners, chicken and turkey pies, chicken a la king, etc.) have appeared on the market. Canned poultry items represent about 5 per cent of the total production as estimated by the volume certified for canning (C-3).

2. General problems

At the annual meeting of the Institute of American Poultry Industries Research Council, comprised of members from the industry, government, and education, current problems of the poultry and egg industries are discussed and recommendations made to the U.S.D.A. for industrial research needs. Although many of these problems may not relate directly to the use of chemicals, it might be of interest to refer to the council's recommendations.

Processing and storage pose a number of specific problems. During processing, for example, unsightly bruises may develop from injuries that occur when the birds struggle during transport and slaughter. Electric shock applied to the birds before they are killed will reduce bruising. The possible use of chemicals to immobilize poultry before slaughter merits investigation. A blanket of carbon dioxide sometimes is used to immobilize swine prior to killing; perhaps a similar approach could be used in poultry processing.

The birds usually are "scalded" by being sprayed or dipped in water of specified temperatures and times. The "scald water" often contains softening and wetting agents which facilitate the process. The feathers generally are removed by placing the scalded bird against moving rubber fingers mounted on a rotated drum, but it has been shown that excessive beating by these fingers toughens poultry meat. Perhaps a chemical agent could be found which, when added to the scald water, would further

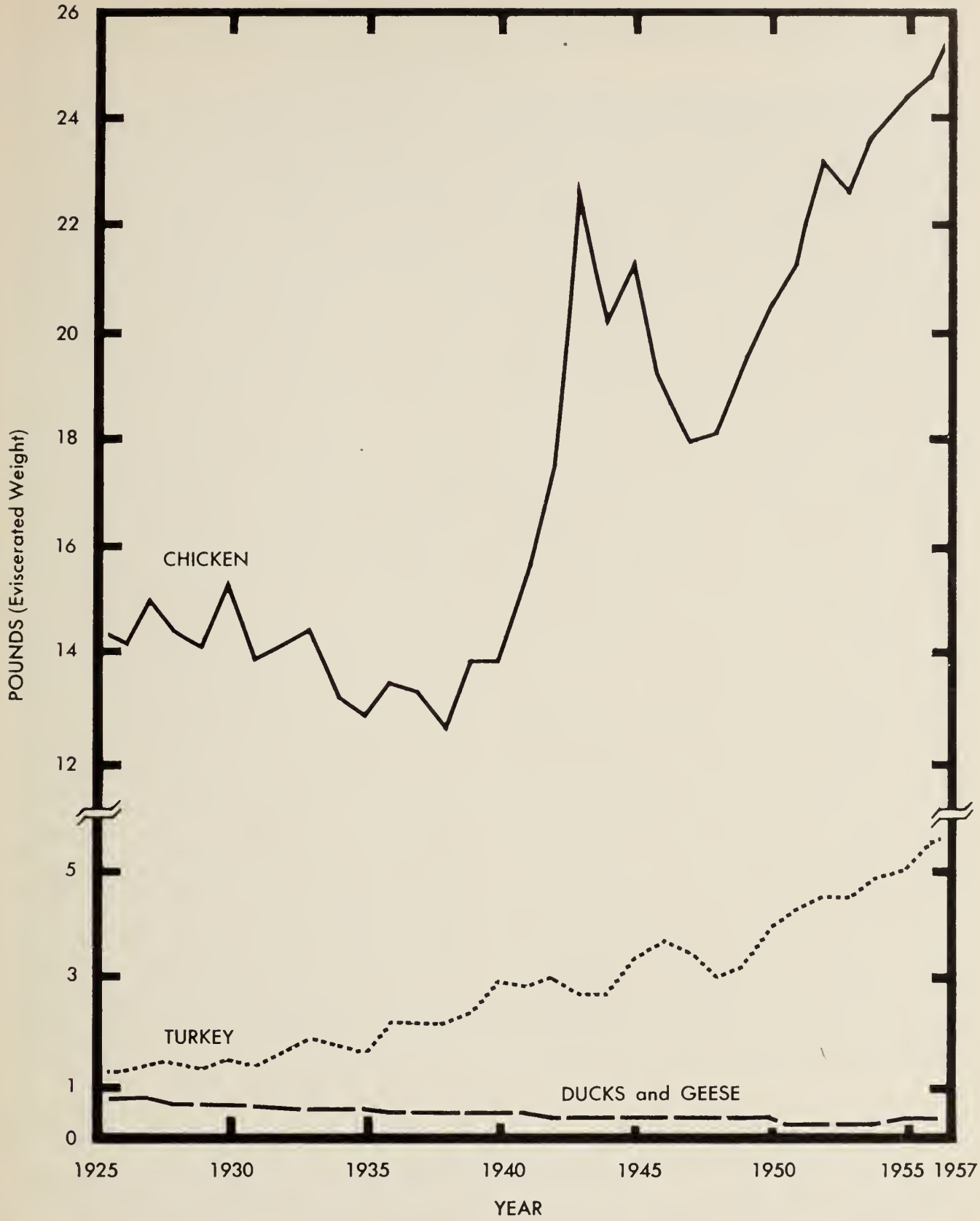


Fig. C-1. U.S. per capita consumption of poultry (approximate retail weight).

facilitate the removal of feathers without impairing the bird's tenderness. Another approach might be to induce feather molting before processing by means of a chemical which could be fed several days ahead of time.

Another processing problem is bleeding. The appearance of the carcass is dependent on the thoroughness of bleeding (C-4), and although salt is sometimes added to the chilling tanks to draw blood, this practice is not entirely satisfactory.

Here, again, appropriate chemicals might solve the difficulty.

The shelf life of chilled poultry has been slightly lengthened by the use of antibiotics (C-5, C-6, C-7), although this has decreased appreciably since it was originally reported. Some believe that this decrease is due to the development of resistant organisms. If this is so, occasional changes to new antibiotics, or perhaps even to synthetic chemicals, may be necessary in order to control the growth of spoilage organisms. Another approach to the problem is to reduce the initial bacterial load at the time of packaging. Any method of lowering the number of organisms originally present would, of course, increase shelf life. Ayres' (C-8) suggestion regarding investigation of a wider use of detergent and sanitizing agents during processing also may be applicable.

The Institute of American Poultry Industries Research Council has recommended to the U.S.D.A. Poultry Advisory Committee that research on tenderness in poultry, particularly frozen turkey and chicken, be continued and expanded (C-9, C-10, C-11). The age of the bird is the first consideration. However, such aspects of processing as aging after killing, scalding temperatures, excessive soaking, scalding water, and excessive beating during feather removal all affect the tenderness of poultry meat (C-12). Perhaps chemicals could help alleviate this problem.

Precooked frozen poultry items have brought complaints of lack of flavor and off-flavor such as rancidity or staleness. To prevent rancidity, wider use should be made of the heat-stable antioxidants. Another solution to this problem is the possibility of adding antioxidants to the feed. Some work has already been done on this approach, but because of the amount of antioxidant needed, the practice is now economically unfeasible (C-13, C-14). The problem of improving the flavor of frozen precooked chicken and turkey will require considerable research, and perhaps additives can be found which will be suitable for the purpose.

A number of articles have been published on the potential hazards of frozen precooked poultry items (C-15, C-16, C-17, C-18), which provide excellent media for the growth of pathogenic organisms. Under proper processing and handling procedures, there is no danger; the hazard lies in allowing these items to stand after they have been prepared and before they are frozen, or allowing them to stand for a long time after thawing. An agent is needed which will prevent the growth of hazardous organisms under such conditions.

LITERATURE CITED

C-1. United States Department of Agriculture, Bureau of Agricultural Economics
1953. Consumption of food in the United States 1909–1952. Agriculture Handbook No. 62 (Sept.; Suppl. July 1958).

C-2. Pennington, M. E.
1951. Poultry and eggs. In The Chemistry and Technology of Food and Food Products, ed. by M. B. Jacobs. Interscience Publishers, Inc., New York.

C-3. Lineweaver, H., and A. A. Klose
1955. Poultry products. In Handbook of Food and Agriculture, ed. by F. C. Blanck. Reinhold Publishing Corporation, New York.

C-4. Davis, L. L., and M. E. Coe
1954. Bleeding of chicken during the killing operation. Poultry Sci. 33, 616.

C-5. Broquist, H. P., A. R. Kohler, and W. H. Miller
1956. Retardation of poultry spoilage by processing with chlorotetracycline. Jour. Agr. Food Chem. 4, 1030.

C-6. Ziegler, F., and W. J. Stadelman
1955. The effect of aureomycin treatment on the shelf life of fresh poultry meat. Food Tech. 9, 107.
C-7. Kohler, A. R., W. H. Miller, and H. P. Broquist
1955. Aureomycin (chlorotetracycline) and control of poultry spoilage. Food Tech. 9, 151.
C-8. Ayres, J. C.
1955. Microbiological implications in the handling, slaughtering, and dressing of meat animals. Advances in Food Research, 6, 109.
C-9. Anon.
1955. Why are turkeys tough? Poultry Processing and Marketing, 16(11), 20.
C-10. Anon.
1956. Poultry committee asks research for healthy birds and superior products. Poultry Processing and Marketing, 62(3), 15.
C-11. Anon.
1955. Research on the toughness of frozen turkey and chickens. Amer. Egg and Poultry Rev. 17(10), 20.
C-12. Klose, A. A.
1956. Tenderness depends on processing. Poultry Processing and Marketing, 62(11), 10.
C-13. Criddle, J. E., and A. F. Morgan
1957. The effect of tocopherol feeding on tocopherol and peroxide content of turkey tissue. Federation Proc. 6, 247.
C-14. Kummerow, F. A., J. Hite, and S. Kloxin
1948. Fat rancidity in eviscerated poultry. Poultry Sci. 27, 689.
C-15. Straka, R. P., and F. M. Combes
1952. Survival and multiplication of *Micrococcus pyogenes* var. Food Res. 17, 448.
C-16. Proctor, B. E., and A. W. Phillips, Jr.
1947. Microbiological aspects of frozen precooked foods Refrig. Eng., 53, 30
C-17. Saleh, M. A., and Z. J. Ordal
1955. Studies on growth and production of *Clostridium botulinum* in precooked frozen foods. I. Some factors affecting growth and toxin production. Food Res. 20, 332.
C-18. Straka, R. P., and J. L. Stokes
1956. Microbiological hazards of precooked frozen foods. Quick Frozen Foods, 18, (7), 182.

Fish and Fish Products

1. Introduction

Fish and fish products have been estimated to supply the world with approximately 3 per cent of its food. This figure is very close to the percentage of United States consumption, but in countries such as Norway and Japan, the proportion may be as high as 10 per cent. Actually, the food potential of the ocean has barely been tapped. And if one considers the limitations of the world's land areas for agricultural development, it is clear that improved methods of fishing and fish preservation will contribute to a vastly increased use of food from the sea in the future.

During 1956, approximately 5.2 billion pounds of fish were caught in the United States and Alaska, with a value of more than 400 million dollars. Of this catch, almost 30 per cent was disposed of in fresh and frozen form, 23 per cent canned, 1.7 per cent cured, and the remainder converted to by-products or used as bait. The *per capita* consumption of fresh, frozen, canned, and cured fish and shellfish is shown in Figure D-1 (D-1).

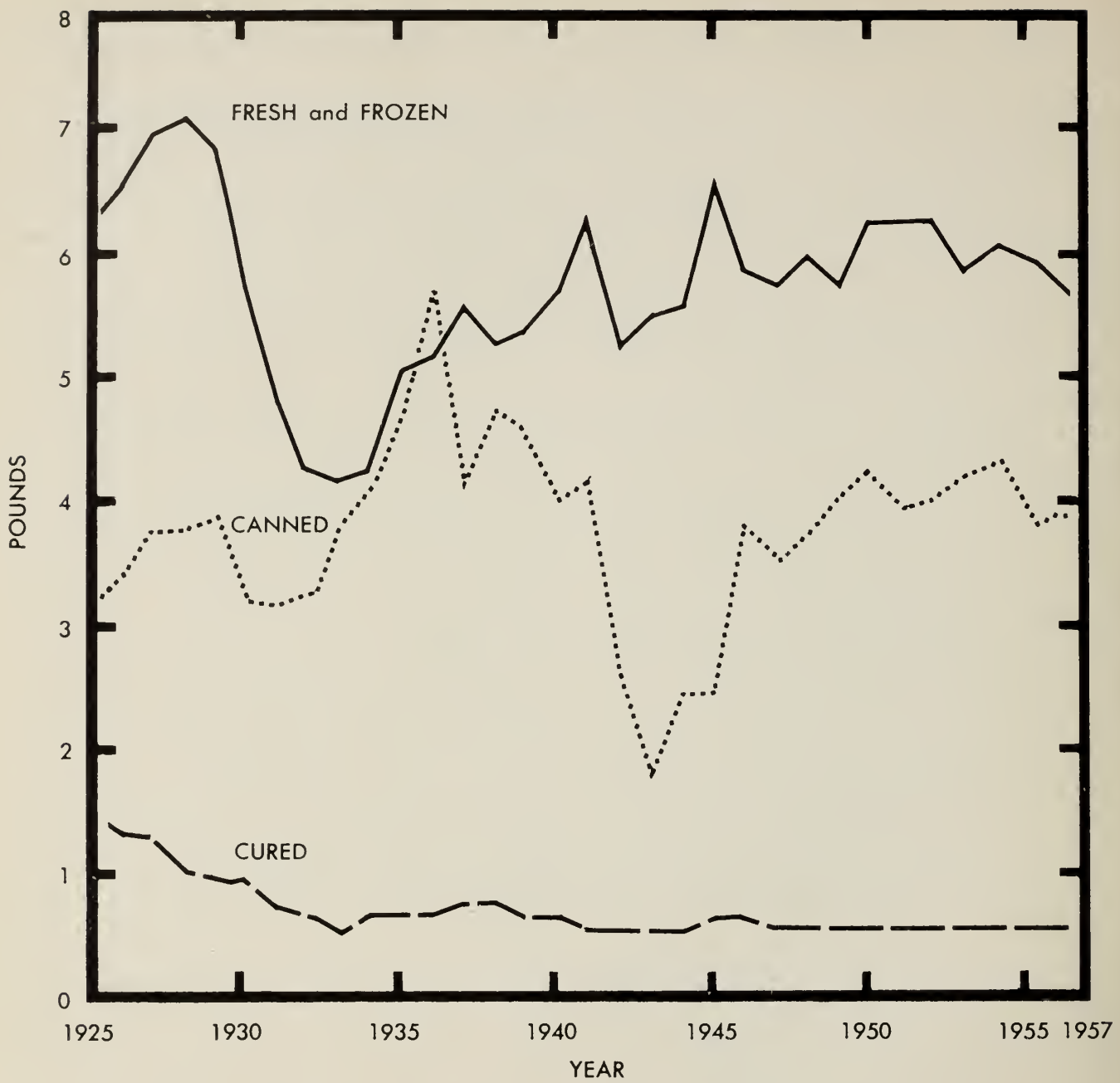


Fig. D-1. U.S. per capita consumption of fish and shell fish.

Detailed information on fishery statistics of the United States can be found in a publication issued by the Fish and Wildlife Service (D-2), and an excellent review of the household consumption of fishery products is available (D-21). The important geographical areas in the United States where fish are landed and processed are Southern California (tuna), the Pacific Northwest (salmon), the Gulf States (shrimp), and New England (cod, sardines, etc.).

Considerable research is being carried out in the United States, as well as in Canada, Great Britain, Japan, and Norway, on improving fish and fish products. Most of the research in the United States has been carried out by government agencies and universities.

2. Commodity problems

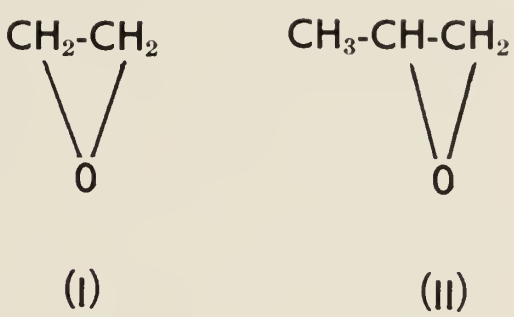
a. Fresh fish

The most important problem with fresh fish is microbial spoilage, which is difficult to control because the organisms involved are pschrophiles, which flourish at low temperatures. In fact, some continue to grow at temperatures as low as –7.5°C. (D-3), and their rate of growth can double when the temperature is

raised from –1° to 2.5°C. (D-4). In some cases, the fishing grounds are so far from port, and/or the time required to catch a full load of fish is sufficiently long to allow spoilage organisms to grow. Because of the practical difficulty involved in maintaining adequate temperatures (at which the growth of psychrophilic organisms is retarded) other means of control have been sought. Numerous investigations have been carried out on the use of chemicals for this purpose. The subject has recently been reviewed in two articles (D-5, D-6).

Among the chemicals that have been tried, probably the most effective is antibiotic treatment (D-7, D-8). In 1956, Ingram (D-9) reviewed the use of antibiotics for the preservation of meat and fish and found that resistant organisms can develop if the antibiotic is used at bacteriostatic concentrations. In addition to antibiotics sodium nitrite has also been found effective in retarding microbial spoilage. The use of both of these agents is now permitted in Canada, but only Aureomycin is permitted in the United States.

Storage under carbon dioxide also has been investigated, and it has been found that an atmosphere containing 50 per cent carbon dioxide retards microbial spoilage (D-10). The use of ethylene oxide (I) and propylene oxide (II) has been investigated, and both have been found to be extremely effective against microbial spoilage, however, the delete-



(I) (II)

Red Chinook salmon being unloaded at a frozen fish plant in Seattle. (Safeway News photo.)

rious effect on the quality rules out their use.

Tarr (D-5) has suggested further investigations on the nutrient requirements of the spoilage organisms in fish. Although antibiotics and nitrite are quite effective in controlling microbial spoilage in fish, the search for even more effective agents should not be abandoned.

b. Frozen fish and shellfish

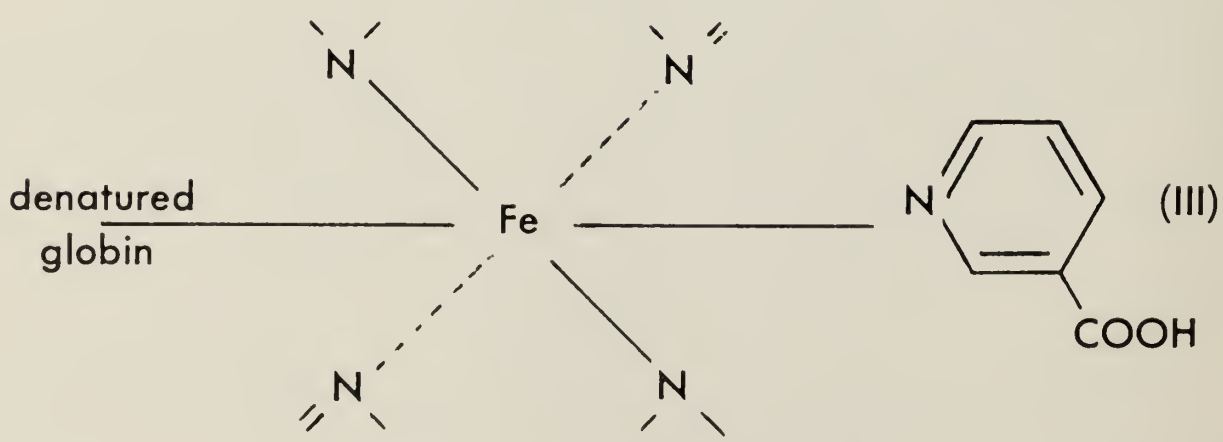
During 1954, approximately 600 million pounds of fish and shellfish were frozen, of which 19 per cent was shrimp, 15 per cent ocean perch, 11 per cent halibut, 10 per cent whiting, 7 per cent bait and animal food, and 7 per cent haddock. The proper freezing of fish prevents microbial spoilage but leads to other problems.

According to Tarr (D-11), the single most serious deterioration which takes place in frozen fish is denaturation of the protein myosin. The exact nature of this deterioration, which may be responsible for the toughening and drying observed in frozen fish and shellfish, is still unknown, and the only available method for combating it is to store frozen fish below –20°C.

Another problem in the preservation of frozen fish is that oxidation takes place which can lead to loss in flavor, development of off-flavors through oxidative rancidity, and discoloration of white-flesh fish or fading of highly pigmented fish, such as salmon (D-12). The addition of an antioxidant retards deterioration (D-13, D-14), but there is controversy in the industry over its possibly unbeneficial effects. Undesirable results from antioxidants have been attributed to insufficient treatment and to improper handling of the fish; thus, an antioxidant is needed which will be really effective (D-15).

Large quantities of carcass fish may be stored frozen until sold or processed. After freezing, the fish is frequently dipped in water; the adhering water freezes to form a protective coating of ice. This coating, referred to as glaze, prevents dehydration and retards oxidation. One difficulty with this process is that the glaze must be reapplied from time to time. An additional difficulty is that pores develop through which oil may seep to the surface and rancidify. Numerous processors have their own formulas for improving the glaze, but the inherent problems still remain. A substitute for glaze is needed; a suitable plastic coating might, perhaps, be the answer.

Another problem of frozen fish is excessive "drip" on thawing; in some extreme cases as much as 10 per cent of the fish's weight may be lost. It would be highly desirable to retain more of this liquid in the flesh so as to reduce "dryness" after cooking. Polyphosphates, which are used to retain juice in meat, might find use in this connection.



c. Canned fish

Discoloration, common in the canning of light-colored fish, has been attributed mainly to the Maillard reaction (between ribose and amine). Tarr (D-16) has suggested that this problem might be solved if ribose could be removed by enzymatic action just as glucose is removed in the production of dehydrated eggs.

A problem in grated canned tuna is retention of the light pink color; it is easily oxidized to tan or brown. A method for restoring or maintaining its color is highly desirable. Brown and Tappell (D-17) have reported that this pink color is due to a pigment-niacin complex (III).

During the past few years, there have been sporadic occurrences of black discoloration in solid-pack tuna, apparently due to the formation of ferrous sulfide and occasionally, of tin sulfide (D-18). A similar discoloration has been occurring in canned wet-pack shrimp (D-19).

d. Cured fish

When smoked, salted, or dehydrated fish is stored, the moisture content may be sufficient to support the growth of mold. Boyd and Tarr (D-20) have reported that such growth on smoked fish is effectively delayed by the use of sorbic acid (IV).

$$CH_3 - CH = CH - CH = CH - COOH.$$

(IV)

A problem in the storage of salted fish is "rusting." The actual nature of rusting is unknown, but it may be due to fat oxidation, and perhaps to the interaction of fat with proteins. In some establishments, losses of salted mackerel due to rusting amount to as much as 25 per cent. An antioxidant or a combination of antioxidants might be developed which would help to relieve this difficulty.

LITERATURE CITED

D-1. United States Department of Agriculture, Bureau of Agricultural Economics
1953. Consumption of food in the United States 1909–1952. Agriculture Handbook No. 62 (Sept. Suppl. July 1958).

D-2. United States Department of the Interior, Fish and Wildlife Service
1954. Fishery Statistics of United States, 1954. Statistical Digest No. 39; also more recent issues.

D-3. Bedford, R. H.
1933. Marine bacteria of the northern Pacific Ocean. The temperature range of growth. Contribution Canad. Biol. and Fisheries **7**, 491.

D-4. Hess, E.
1932. The influence of low temperatures above freezing upon the rate of autolytic and bacterial decomposition of haddock muscle. Contribution Canad. Biol. and Fisheries, **7**, 147.

D-5. Tarr, H. L. A.
1954. Microbiological deterioration of fish *post-mortem*, its detection and control. Bacteriol. Rev., **18**, 1.

D-6. Tomiyasu, Y., and B. Zenitani
1957. Spoilage of fish and its preservation by chemical agents. Advances in Food Research **7**, 41.

D-7. Boyd, J. W., H. M. Bluhm, C. R. Muirhead, and H. L. A. Tarr
1956. Use of antibiotics for the preservation of fish and sea foods. Amer. Jour. Public Health, **46**, (12), 1531.

D-8. Firman, M. C., A. Abbey, M. A. Darken, A. R. Kohler, and S. D. Upham
1956. Effect of aureomycin (chlorotetracycline) on fish freshness. Food Tech. **10** (8), 381.

D-9. Ingram, M., E. M. Barnes, and J. M. Shewan
1956. Problems in the use of antibiotics for preserving meat and fish. Food Sci. Abs. **28**, 121.

D-10. Stansby, M. E., and F. P. Griffiths
1935. Carbon dioxide in handling of fresh fish. Ind. Eng. Chem. **27**, 1452.

D-11. Tarr, H. L. A.
1955. Sea foods. In Handbook of Food and Agriculture, ed. by F. C. Blanck. Reinhold Publishing Corporation, New York.
D-12. Brown, W., A. L. Tappel, and M. E. Stansby
1956. Oxidative deterioration in fish and fishery products. Com. Fisheries Rev. **18**, (2), 10.
D-13. Anon.
1955. Antioxidant mixture used in frozen fish. Food Field Reporter, **23** (11), 28.
D-14. Watts, B. M.
1955. Deteriorative changes in frozen shrimp and their inhibition. Food Tech. **9**, 632.
D-15. Tarr, H. L. A.
1956. Research on fish preservation and processing. Food Manuf. **31**, (6), 239.
D-16. Tarr, H. L. A.
1954. Maillard reaction in flesh food. Food Tech. **8**, 15.
D-17. Brown, W. D., and A. L. Tappel
1957. Identification of the pink pigment of canned tuna. Food Res. **22**, 214.
D-18. Pigott, G., and M. E. Stansby
1955. Iron sulfide discoloration of tuna cans. Com. Fisheries Rev. **17** (10), 34.
D-19. Landgraf, R. G., Jr.
1956. Factors influencing the sporadic development of discoloration in canned wet-pack shrimp. Food Tech. **10**, 607.
D-20. Boyd, J. W., and H. L. A. Tarr
1955. Inhibition of mold and yeast development in fish products. Food Technol. **9**, 411.
D-21. Shere, H.
1958. Use of fishery products by households in spring.
1955. The National Food Situation, October, p. 19.

Dairy Products

1. Introduction

In 1957, dairy products, excluding butter, accounted for approximately 28 per cent of the retail weight of the food consumed in this country; they therefore stood first in importance, on a weight basis. Their nearest competitors were the fruits and vegetables, amounting to 13.7 per cent of the total food retail weight. Dairy items, including butter, cost 16.2 cents of each food dollar, and they contributed 14 per cent of the food energy, 25 per cent of the protein, 77 per cent of the calcium, and almost 50 per cent of the riboflavin in the American diet (E-1). The *per capita* consumption of some of these products is shown in Figure E-1.

The use of fresh, whole milk remained remarkably constant from the end of World War I to 1942, at about 260 to 270 pounds per person annually (retail weight). During World War II, consumption increased to well above 300 pounds. On the other hand, the use of dairy cream, which was at an almost constant level of 11 pounds per person annually for 50 years, has steadily declined since 1946 to a 1957 level of 7.4 pounds. Natural buttermilk has shown an almost uninterrupted decline in *per capita* use from a level of almost 70 pounds at the turn of the century to about 26 pounds in 1957 (E-1).

In considering additives for dairy products, public feeling must be taken

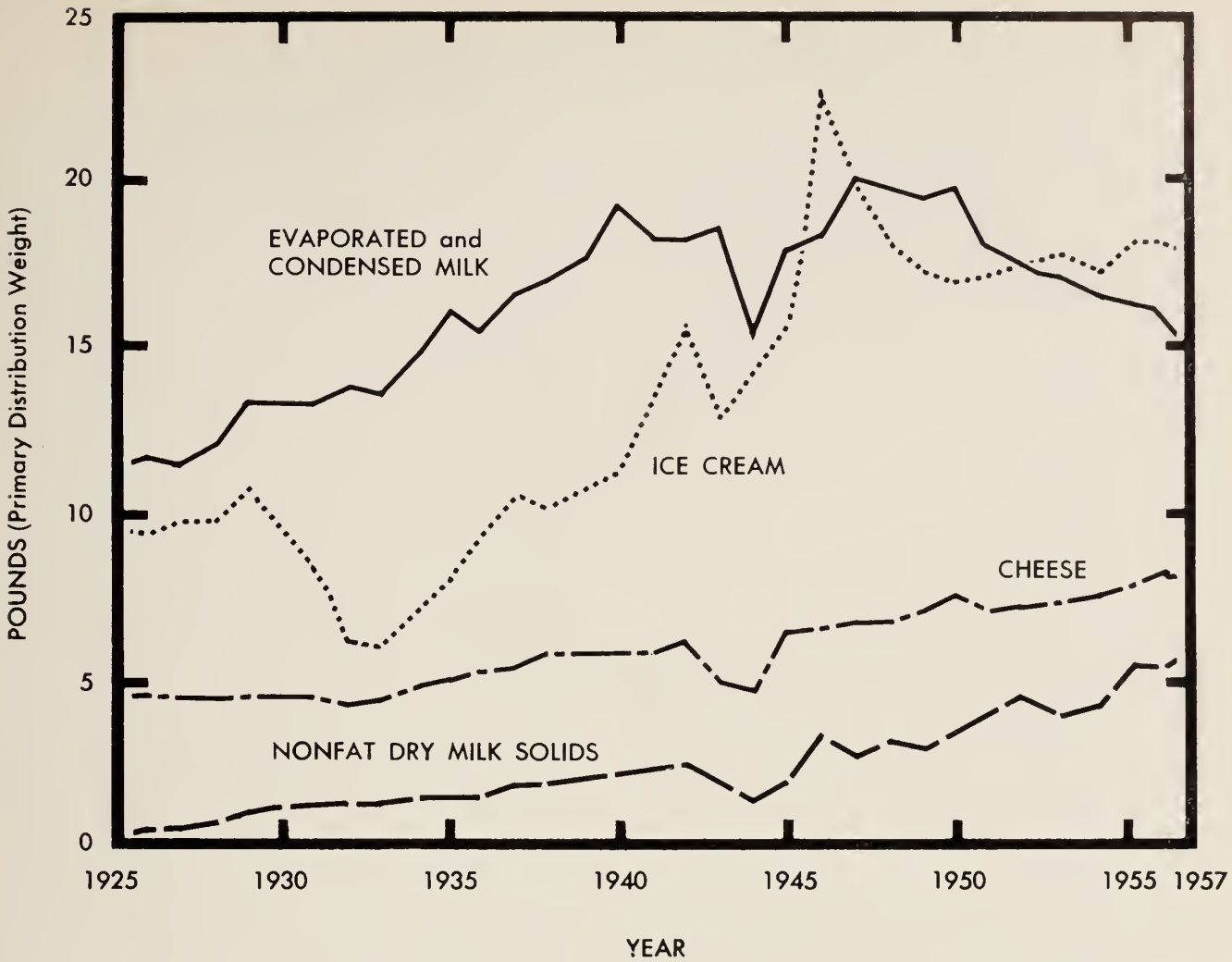


Fig. E-1. U.S. per capita consumption of dairy products.

into account. Because gross adulterations were discovered in the early days of the milk industry, there was established legislation prohibiting the addition of practically anything to milk. The feeling has developed that milk is sacred, and the first of the Ten Commandments of the Dairy Industry is, "Thou shalt not alter." However, milk as it comes from the cow is not necessarily an ideal food, and perhaps if the need exists, it should be altered to meet specific requirements. The stability of dairy products *can* be improved through the intelligent use of proper additives and this fact could be recognized by the industry (E-2).

2. Commodity problems

a. Milk

1) *Fresh milk.* Approximately 75 per cent of the total consumed weight of dairy products is in the form of fluid milk and cream. One of the principal problems encountered in fluid milk is off-flavor; feed odors, oxidation, rancidity, exposure to sunlight, and microbial spoilage are only a few of the possible contributory factors.

In their review of the literature devoted to flavors of milk, Strobel and coworkers (E-3) note that most of the studies have been concerned with oxidized flavor; this is an indication of the importance of this form of deterioration. The susceptibility of individual lots to oxidized flavor is extremely variable and is markedly influenced by the feed of the cow (E-4). Development of oxidized flavor is catalyzed by light or by contamination with copper or iron; it is retarded by homogenization and the addition of antioxidants (E-5, E-6, E-7, E-8).

The use of the antioxidant ascorbic acid is relatively limited, since its addition is prohibited in most states (E-9). Therefore, the adding of antioxidants and perhaps chelating agents to milk will have to await the repeal of present laws.

Rancid off-flavors result from the action of lipase present in the milk (E-10, E-11). Many investigators believe that fat in milk is surrounded by a thin film of lipoprotein which protects the fat from lipase. When this protective film is ruptured, the lipase is then able to exert its hydrolytic action. In recent years, the lipase enzymes have been found to be activated by agitation of the warm milk in milker pipelines. Better temperature control and reduction of agitation might remedy the problem; however, it might also be alleviated by a suitable additive that would inactivate the enzyme.

Milk drawn from a healthy cow usually contains relatively few microorganisms; contamination usually occurs during subsequent handling. Pasteurization eliminates pathogenic organisms and those that bring about common deterioration, but spoilage may still be induced by the growth of organisms which survive pasteurization temperatures or enter milk by contamination after pasteurization. Antibiotics have been investigated for their possible value in retarding spoilage (E-12, E-13), but their use exchanges one problem for another; antibiotics in milk inhibit the growth of the desirable organisms needed in the production of cheese, sour cream, buttermilk, etc. An alternative to antibiotics, hydrogen peroxide, has been suggested, since it has the advantage over antibiotics that its bacteriostatic action soon ceases (E-14). It might be possible to supplement pasteurization with additives that would eliminate the organisms which survive it, or additives might be developed which would replace pasteurization altogether.

In an attempt to equilibrate milk production with consumption, milk has been concentrated and frozen. But one difficulty encountered was the gelation of casein, considered to be triggered by lactose crystallization. A chemical additive might be found which would prevent or delay lactose crystallization (E-15).

2) *Evaporated milk.* The intensive heat treatment required to achieve sterility has two undesirable consequences: a change in flavor, and in color (due to browning reaction). To retain more of the fresh milk flavor, one processor uses a high-temperature short-time process, but this product gels on storage (E-16). A suitable additive might provide a solution to the problem.

It seems clear that milder heat treatments would reduce both changes in fresh milk flavor and the browning reaction. The use of lower heat would then entail some method of controlling gelation. Another approach to the problem would be through the use of additives.

3) *Dried milk.* The consumption of nonfat milk solids is increasing steadily; on the other hand the development of an acceptable whole-milk powder has been rather slow because of the problems of flavor retention, storage stability, and facility of reconstitution. Additives may be the ultimate solution to these problems.

Certain surfactants, when added to the milk before spray-drying, have been found to improve the dispersibility of dry whole milk; combinations of Tween 60 and Span 60 were found to be most efficient (E-2). To increase the storage stability of whole-milk powder, the hydrogenation of butterfat has been suggested, as has the use of other stabilized fats to overcome oxidative rancidity. The use of antioxidants and an effective oxygen scavenger has also been suggested.

b. Cheese

To retain texture and flavor, cheese must be coated or kept in a very moist atmosphere; under these conditions, however, it is highly susceptible to mold

growth. It was estimated in 1952 that about 13 million pounds of cheese could have been saved through the use of an effective fungistatic agent (E-17) such as sorbic acid and propionic acid salts, the use of which is now permitted by FDA.

A number of types of cheese acquire their unique characteristics through the development of particular microorganisms. Maintaining the growth of certain organisms to the exclusion of others presents a problem, and an agent which would restrict the growth of the undesired organisms would be helpful in cheese processing. Such an agent might be developed through studies of the nutritional requirements of both desirable and undesirable organisms.

The development of a method for extending the shelf life of cottage cheese would be valuable. Organisms responsible for a slimy or gelatinous curd which forms, and molds and yeasts which cause changes in flavor, odor, and appearance are a problem in the distribution of this cheese.

c. Ice cream

In contrast to milk, a variety of additives are used in the production of ice cream. Flavoring agents, stabilizers and emulsifiers are included in most formulas (E-10, E-18), in addition to the basic milk, cream, and sugar. The stabilizers produce and maintain a smooth, creamy texture by absorbing or binding a portion of the water in an ice-cream mix and thus preventing it from freezing into large, grainy crystals. Stabilizers classify into two types: Carbohydrates (Irish moss, alginates, locust bean gum) and protein (gelatin and milk protein), and many of them have distinct disadvantages.

Irish moss produces excessive viscosity and is unsuitable as a sole stabilizing ingredient because it produces very weak-bodied ice cream. Carboxymethyl cellulose produces a "wheyed-off" condition or a mix separation; locust bean and guar gum present the same difficulty, in addition to causing excessive viscosity. Commonly used algin stabilizers are not soluble in the cold mix, and milk proteins are generally not sufficiently concentrated to be useful as a sole stabilizing ingredient.

Emulsifiers are added to ice cream to reduce interfacial tension, and to act as foaming agents. Some of their functional advantages are that the ice-cream mix can be whipped faster, the product from the freezer is dryer, and the mix has less tendency to "churn" in the freezer. In addition the product is smoother and has a finer texture. Chemical compounds used as emulsifiers are mono- and di-glycerides, polyoxyethylene and sorbitan derivatives, and egg yolk. The mono- and di-glycerides are very effective and are generally accepted by the ice-cream industry. Some question has been raised, however, as to the toxicity of the polyoxyethylene derivatives. Egg yolk is more expensive to use and has poor keeping quality.

Flavor deterioration is not an important problem in ice cream because of the low storage temperatures and the relatively rapid sales turnover of ice cream. The industry is still confronted by the problem of shrinkage from the sides of the container during storage. This shrinkage is due to a loss of the air incorporated in the mix and the subsequent collapse of the structure; during storage the surface becomes rubber-like, and gives the appearance of not being fresh.

LITERATURE CITED

E-1. United States Department of Agriculture, Bureau of Agricultural Economics
1953. Consumption of food in the United States 1909–1952. Agriculture Handbook No. 62 (Sept. Suppl. July 1958).

E-2. McIntire, J. M., W. K. Stone, and M. S. Peterson
1954. Dry milk products. A symposium sponsored by the Quartermaster Food and Container Inst., Chicago, Illinois.

E-3. Strobel, D. R., W. G. Bryan, and C. J. Babcock
1953. Flavors of milk, a review of literature. United States Department of Agriculture Pamphlet.

E-4. Dunkley, W. L.
1955. Off flavors can be prevented. Hoard's Dairyman, **100**, 400, 409 (April 25)

E-5. Lucus, E.W., E. W. Bird, and W. S. Rosenberger
1956. The possibility of copper-induced oxidation of milk in stainless steel-white metal systems. Jour. Dairy Sci. **39**, 1487.

E-6. Tollenaar, F. D., and D. A. Mossel
1953. The use of chemicals in dairy products. Proc. XIII International Dairy Congress 3, 1831.

E-7. Chilson, W. H., W. H. Martin, and C. H. Whitnah
1950. Use of propyl gallate to defer development of oxidized flavor of market milk. Jour. Dairy Sci. 33, 935.

E-8. Sievers, F. S.
1954. Antioxidant for dairy products. Massachusetts Agr. Exp. Sta. Bull. 428.

E-9. Bauernfeind, J. C.
1953. The use of ascorbic acid in processing foods. Advances in Food Research 4, 359.

E-10. Tarassuk, N. P., and E. N. Frankel
1955. Technical notes on the mechanism of activation of lipolysis and the stability of lipase systems of normal milk. Jour. Dairy Sci. **38**, 438.

E-11. Herrington, B. L.
1956. Control of rancidity in milk. Jour. Dairy Sci. **39**, 1613.

E-12. Angelotti, R., H. H. Weiser, W. L. Slatter, and I. A. Gould
1955. Effect of antibiotics on microflora of milk. Applied Microbiology, 3, 234.

E-13. Anon.
1956. Antibiotics use seen in milk, vegetables, frozen and canned food. Food Field Reporter, **24**, (6), 50.

E-14. Dahlen, M. A.
1945. Hydrogen peroxide of high purity and its use for sterilization of milk. United States Department of Commerce, Office of Technical Service, P. B. 31003.

E-15.
1956. Chemical additive sought for frozen milk concentrate. Food Tech. in Australia, **8**, 11, 644.

E-16. Tarassuk, N. P., and A. F. Tamsma
1956. Control of gelation in evaporated milk. Jour. Agr. Food Chem. 4, 1033.

E-17. Smith, D. P. and N. J. Rollin
1954. Sorbic acid as a fungistatic agent for foods. Food Tech. **8**, 133.

E-18. Redfern, R. B. and W. S. Arbuckle
1949. Review of stabilizers and emulsifiers in ice cream production. Southern Dairy Products Jour. **46**, (3) 32, 38 and 48.

E-19. Weinstein, B. R.
1956. The current status of stabilizers in ice cream. Ice Cream Trade Jour. **32** (Oct.).

E-20. Decker, G. C.
1959. Significance of pesticide residues in milk and meat. Jour. Agr. Food Chem. **7**, 681.

E-21. Patton, S.
1958. Review of organic chemical effects of heat on milk. Jour. Agr. Food Chem. **6**, 132.

Eggs

1. Introduction

Eggs rank next after beef, pork, and milk on the consumer's food budget. It was shown in Table 1 of Part I that 6.3 per cent of the food dollar was spent on eggs between 1947 and 1949, and the general upward trend in the *per capita* consumption of eggs since 1935 also was indicated. During 1957, 4.5 per cent, or about 3 billion dollars, was spent on eggs (F-1). Although they supplied only 2.6 per cent of our food energy, eggs provided 6.6 per cent of the protein, 8.5 per cent of the iron, and 7.9 per cent of the Vitamin A in U. S. diets.

Of the 65 billion eggs available in 1957, approximately 90 per cent were consumed as shell eggs; the remainder were converted to frozen and dried eggs, or were sold to hatcheries (F-2).

2. Commodity problems

a. Shell eggs

Eggs are cleaned, graded according to size, and candled for quality. If they are to be kept in cold storage, they generally are coated with mineral oil to maintain quality (F-3, F-4).

It was estimated that in 1947 the total loss of eggs between producer and consumer was 26 per cent, worth 650 million dollars (F-5). Trussell and co-workers (F-6) found that in British Columbia, 70 per cent of the farms submitted eggs for marketing of which at least 1 per cent were infected with spoilage organisms, as the result of washing.

Eggs are usually sterile when laid, but become infected through the pores of the shell by organisms picked up in the nest and during handling. Microbial contamination takes place with particular ease when eggs are wet, and considerable research has been done on the efficacy of various agents in the wash water in the reduction of microbial spoilage (F-7, F-8). Thermal stabilization has also been studied quite extensively (F-9). Neither procedure has worked well in practical application, however, and effective methods of reducing microbial spoilage would be of considerable value (F-10).

Fumigation with ethylene oxide has been reported to reduce markedly bacterial spoilage of cold-storage eggs (F-11), but sterilizing dosages caused the candling grade to drop from A to B, and also produced some liquefaction of the albumen. It has been suggested that even mild fumigation would be economically advantageous because of the considerable reduction in spoilage it effects. Further investigations should be carried out on this method of treatment, perhaps with other chemicals.

In addition to being subject to microbial spoilage, eggs can deteriorate in quality when exposed to warmth, due to the stimulation of embryonic development in fertilized eggs, and the increase in chemical action in unfertilized eggs. Eggs stored between 29° and 30°F. can be kept acceptably for more than 6 months, although the flavor and cooking quality of cold-storage eggs do undergo change. The possibility of using some agent to maintain the flavor and physical properties of fresh eggs should be investigated.

b. Frozen eggs

In 1953, 5.7 per cent of the available eggs were processed, and of these 4.7 per cent were frozen. Most frozen eggs are processed during the period of peak production (March to June); and because of their uniformity of composition, are used extensively by the baking industry.

A difficulty which arises both with frozen whole eggs and yolks when they are stored frozen, is gelation (F-12), which makes for inconvenience in use. Sugar, salt, or glycerol may be used to retard this thickening, but the addition of salt and sugar to frozen whole eggs or yolks limits their use primarily to the production of mayonnaise, confectionery, and baked products. The development of an additive which would prevent gelation and impart little or no flavor would make it possible to extend the use of frozen whole eggs to the home kitchen. Experiments on use of enzymes to prevent gelation have been reported (F-13).

A problem met with in frozen egg-white is the occasional presence of iron, which imparts an undesirable pink color. The iron might be removed by use of a suitable chelating agent.

c. Egg solids

Dried eggs were produced in considerable quantity during World War II for the armed forces. Their chief drawback was poor storage stability; at the time of packing the quality was excellent. Since then, the storage stability of egg solids has been greatly improved by acid-stabilization prior to drying and, more recently, by the removal of glucose by means of enzymes or yeast (F-14).

The production of egg solids was curtailed at the end of the war, but is steadily increasing because of their inclusion in the convenience items such as packaged cake mixes, commercial doughnut mixes, etc. Also, the increased storage stability and higher quality of egg solids are making them more acceptable to bakers and noodle manufacturers.

Although a number of improvements have been made in the techniques for preserving egg solids over the past 10 years, some problems are still to be solved. The industry needs an agent which will eliminate the pathogen *Salmonella* (F-14) from egg solids, and also some means for retaining more of the flavor and leavening power.

LITERATURE CITED

F-1. United States Department of Agriculture, Bureau of Agricultural Economics
1953. Consumption of food in the United States 1909–1952. Agriculture Handbook No. 62 (Sept. Suppl. July 1958).

F-2. Lineweaver, H., and A. A. Klose
1955. Poultry products. In Handbook of Food and Agriculture, ed. by F. C. Blanck. Reinhold Publishing Corporation, New York.

F-3. Sherman, H. C.
1948. Eggs dipped in mineral oil for cold storage. In Food Products, 4th ed., The Macmillan Co., New York.

F-4. McLaren, B., and W. J. Stadelman
1955. The flavor of your eggs. Poultry Processing and Marketing, **61**, (2), 20.

F-5. Buster, M. W.
1948. Losses of poultry products in channels of trade. Abstracts of Poultry Sci. **27**, 655.

F-6. Trussell, P. C., C. O. Fulton, and C. J. Cameron
1955. Bacterial spoilage of shell eggs. II. Incidence of spoilage in eggs from 94 farms. Food Tech. **9**, 130.

F-7. Cotterill, O. J., and P. Hartman
1956. Effect of antibiotics on the incidence of spoilage of shell eggs. Poultry Sci. **35**, 733.

F-8. Miller, W. A.
1954. The microbiology of dirty eggs heated in various ways and stored at different temperatures and humidities. Poultry Sci. 33, 735.
F-9. Funk, E. M., J. Forward, and M. Lorah
1954. Minimizing spoilage of eggs by thermostabilization. Poultry Sci. 33, 532.
F-10. Trussell, P. C.
1955. Bacterial spoilage of shell eggs. Food Tech. 9, 126.
F-11. Sawyer, F. M.
1951. Sterilization of eggs with ethylene oxide. M. S. Thesis, University of California, Davis.
F-12. Lopez, A., C. R. Fellers, and W. D. Powrie
1954. Some factors affecting gelation of frozen egg yolk. Jour. Milk and Food Tech. 17, 334.
F-13. Lopez, A., C. R. Fellers, and W. D. Powrie
1955. Enzymic inhibition of gelation in frozen eggs yolk. Jour. Milk and Food Tech. 18, 77.
F-14. Peterson, M. W., and H. E. Groesline
1954. Stability of dehydrated eggs. A symposium sponsored by the Quartermaster Food and Container Inst., Chicago, Illinois.

Fats and Oils

1. Introduction

The consumption of fats and oils in the United States during 1956 was 10.63 billion pounds, of which approximately 72 per cent went for food use (G-1). The latter figure refers only to the fat content of products such as butter and margarine, and does not include fats in meat, eggs, other dairy products, etc. Further breakdown of this figure for individual products is shown in Table G-1. The trends in the *per capita* consumption of these commodities from 1925 are shown in Figure G-1.

Table G-1. Fats and Oils Used in Products for Consumption During 1956.

Commodity	Consumption
	in billion pounds
Butter (actual weight)	1.44
Lard	1.65
Margarine	1.35
Shortening	1.80
Edible Oils	1.65

2. General problems

a. Oxidative rancidity

Oxidative deterioration of unsaturated fats is still one of the industry's most important problems. The addition of antioxidants to fats, oils, and fat-containing foods does greatly delay the onset of this type of rancidity, but although a number of antioxidants are presently permitted in foods, each has its deficiency (G-3). For example, butylated hydroxyanisole (BHA) (I) has a noticeable phenolic odor when heated to high temperatures, such as in deep fat frying; butylated hydroxytoluene (BHT) (II) lacks high potency at low concentrations; nordihydroguaiaretic acid (NDGA) (III) possesses low heat stability, poor oil solubility, and is expensive; n-propyl gallate (IV) possesses low heat stability and poor oil solubility in addition to forming a blue-colored complex in the presence of ferric ions.

Combinations of some of the above antioxidants, in conjunction with synergists, usually retard oxidative rancidity in most commodities. The present market

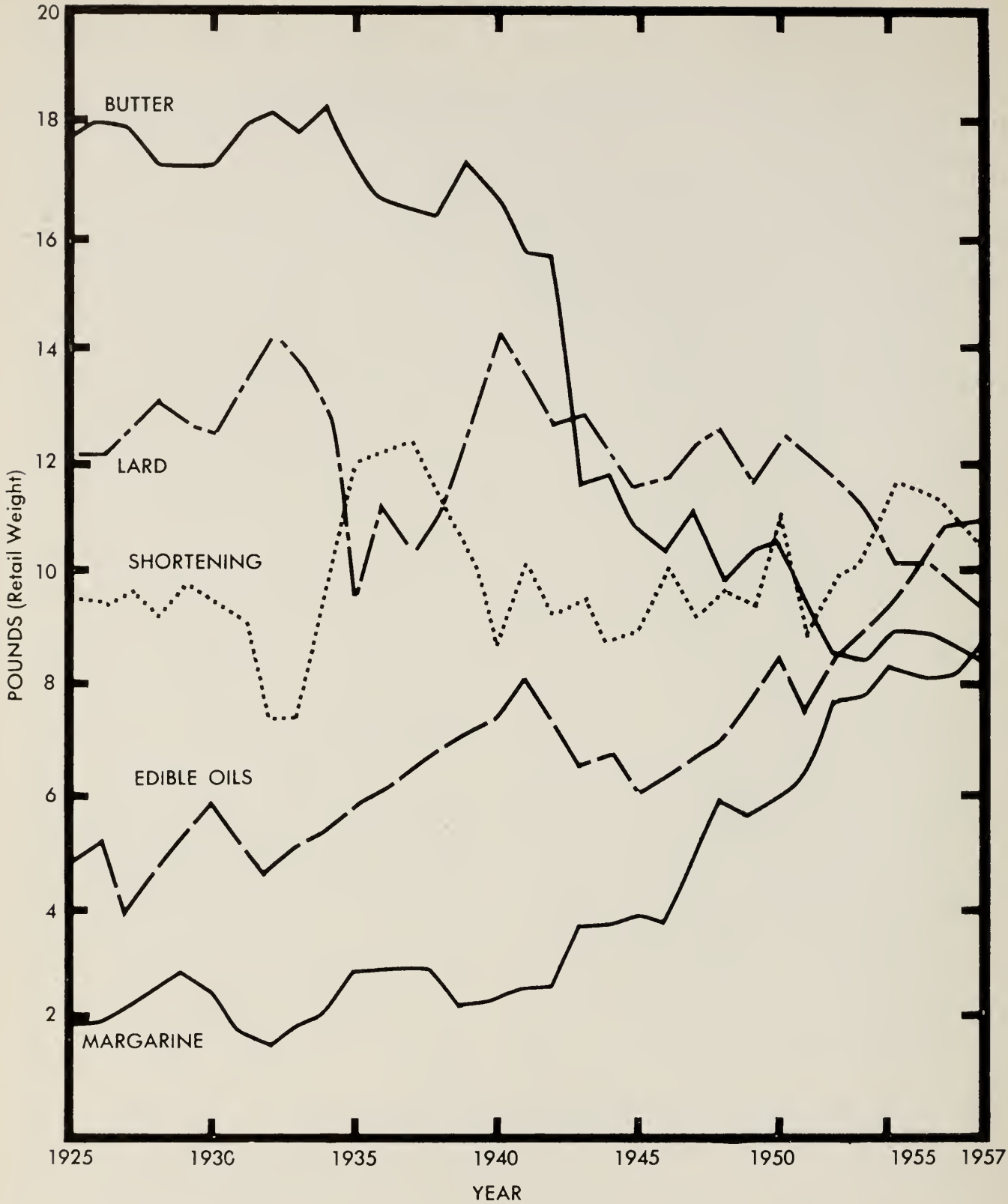
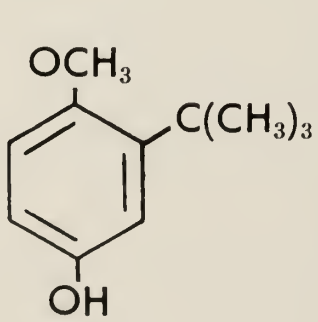
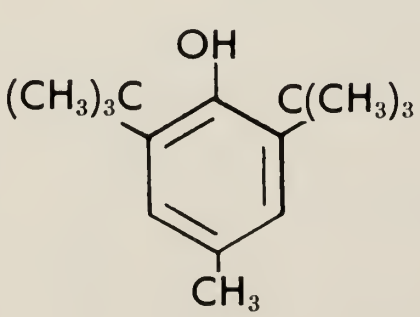


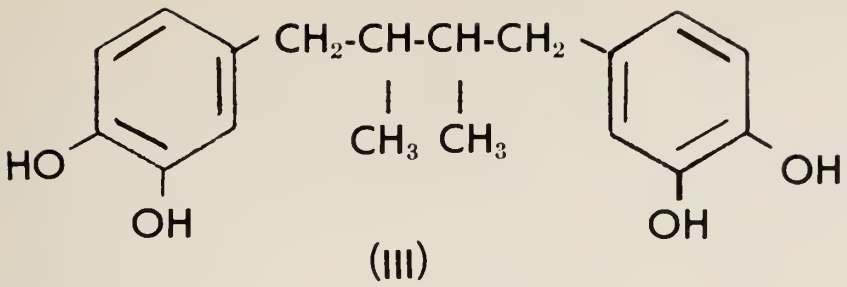
Fig. G-1. U.S. per capita consumption of fats and oils.



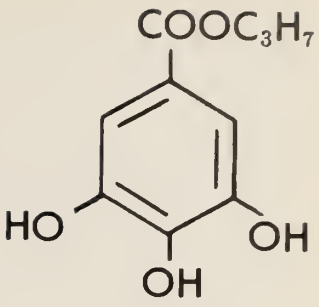
(I)



(II)



(III)



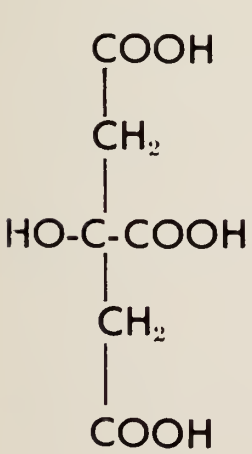
(IV)

for food antioxidants is divided among BHA, BHT and propyl gallate at approximately 55, 25, and 20 per cent, respectively.

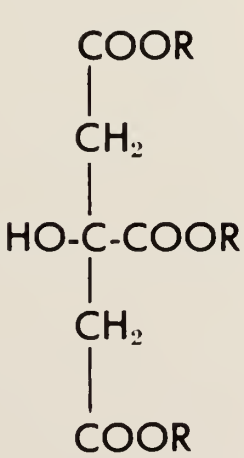
A recent publication stated that the total use of antioxidants for food and feed during 1956 was expected to reach 3 million pounds (G-3), 2 million pounds of which were to be used in poultry feeds. An approximate maximum amount of antioxidants that might be used in human food can be calculated by assuming the addition of 0.01 per cent to the total amount of fats and oils consumed in all commodities. In 1954 approximately 7 billion pounds of fats and oils were consumed in the United States. (About 50 per cent of our total fat intake is from those commodities listed under Fats and Oils; the remaining 50 per cent of our fat is from meat, dairy products, and other foods.) From these figures, it can be calculated at the present time that the maximum potential market for use of antioxidants is about 1.4 million pounds per year.

The presence of metallic ions such as copper and iron is known to catalyze oxidative rancidity in unsaturated fats and oils. The most obvious solution to this problem would be to prevent metal contamination, but in practice this is not always economically possible. The present method for reducing the catalytic effect of dissolved metals involves the addition of a metal complexing agent such as citric acid (V), citrate esters (VI), or phosphoric acid. Other complexing agents such as ethylenediamine tetracetic acid (VII) may be applicable to foods, and another method for removal of contaminating metals might lie in the use of ion exchange resins.

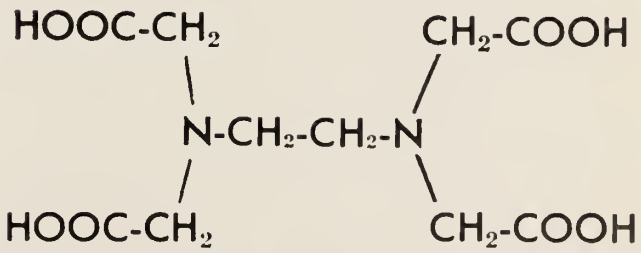
As a result of studies on the relationship between saturated fat intake and the incidence of atherosclerosis (G-4, G-5, G-6), the food industry is currently vitally concerned about what course to take in the handling of saturated fats. It has been estimated that 30 to 60 million of the 170 million in our population will die of atherosclerosis or hardening of the



(V)



(VI)



(VII)

arteries (G-7), and high fat caloric intake (about 40 per cent of the American diet) is held to be a contributory factor in these diseases.

There is some evidence that a readily available source of essential fatty acids may be necessary for the normal metabolism of cholesterol (G-8); there is controversy, however, over the amount of saturated fat which would be beneficial in the diet. More research is needed before adequate recommendations can be made about whether saturated fat intake should be reduced or essential fats added to our diet as a supplement; if results should show the need for the latter, there will be an increased need for antioxidants to control oxidative rancidity.

3. Commodity problems

a. Butter

The following procedures are involved in the production of butter from cream:

1. Neutralization: Reduces acidity. Alkaline salts such as sodium carbonate, magnesium oxide, or calcium carbonate are added to cream.

2. Pasteurization: Enhances the keeping quality of butter and eliminates hazardous microorganisms.

3. Fermentation: "Ripening" by an acid fermentation to develop desirable flavor.

4. Churning: Coalesces butterfat particles into granules of butter.

In 1954 an American Dairy Science Association Committee published a report on butter-improvement (G-9), and pointed out that butter deteriorates during storage as the result of the growth of microorganisms, action of enzymes, and oxidative rancidity.

Bacteria and molds are responsible for much of the deterioration in butter, and although the addition of salt retards their growth, an uneven distribution still permits spoilage. In "sweet" unsalted butter (limited production), microbial growth is a serious problem.

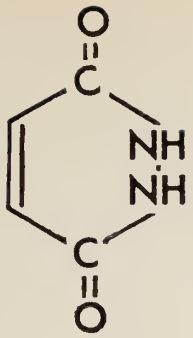
Off-flavors in butter develop with even a slight degree of fat oxidation. Bailey (G-10) considers this deterioration to be "reversion" rather than oxidative rancidity. True oxidative rancidity is not a serious problem since butter is stored at low temperatures, and has a relatively low unsaturation.

b. Lard

The process of obtaining fats from animal tissue is referred to as rendering. The method involves separating the oil by heating the fatty tissue with or without water, or by heating directly with steam. The market for lard was greatly curtailed in the early 1930's by the introduction of more desirable shortenings made by hydrogenating vegetable oils. But, with the recent development of "rearranged lard" [random rearrangement of fatty acids of the triglycerides by the use of sodium methoxide (G-11) or sodium-potassium alloy (G-12)] along with the incorporation of mono- and di-glycerides and antioxidant, lard shortenings have become competitive with others. A need has been expressed for better rearrangement catalysts, since the use of sodium methoxide results in a fat loss of 3 to 4 per cent due to the formation of methyl esters, in addition to the fat loss caused by saponification when water is added to the reaction mixture to remove the catalyst.

c. Edible oils, shortening, and margarine

After harvest and prior to processing, some percentage of oil seeds must be held in storage in order to supply the processing plant over the entire year. During storage, free fatty acids, which form slowly through the action of the lipase enzyme systems, and oil-soluble breakdown products of protein, carbohydrate, and other materials present in the fatty tissue contaminate the oil. Thus, storage conditions must be closely controlled in order to minimize deterioration, and it may be possible to effect additional control by chemical means. Lambow and co-

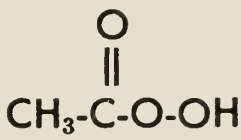


(VIII)

workers (G-13) have shown that the application of maleic hydrazide (VIII), used to defoliate the cotton plant prior to harvest, appears to reduce free fatty acid formation in cottonseed during storage. The use of ammonia or gaseous hydrogen chloride also retards the formation of fatty acids during storage; however, the commercial use of these gases has not been adopted because of their deleterious side-effects (G-14).

Crude oil is obtained from oil-bearing seeds either by mechanical expression or solvent extraction. Soybean and cottonseed meals are high-protein by-products of oil extraction and are primarily used as animal feed. The crude oil is usually refined by neutralizing, bleaching, and deodorizing (G-15). The neutralization step consists of treating the crude oil with an aqueous solution of sodium hydroxide or sodium carbonate to remove not only the free fatty acids, but also the phosphatides, resins, and mucilaginous material. An appreciable quantity of neutral oil is lost (as high as 50 per cent of the residue may be neutral oil) during this step of the process. This excessive loss (due to the inclusion of neutral oil) might be reduced by the use of some chemical agent. "Politol," a combination of phosphates and high molecular weight acidic wood products, and other organic compounds containing NH_2 and OH groups (G-16), are reported to reduce refining losses.

Color removal from excessively dark or green-colored oils is one of the problems in refining edible oils. Presently, Fuller's earth and activated charcoal are most commonly used to reduce color (G-17). Chemical bleaching agents may be of use (G-15) in reducing the color of excessively dark oils. Although chemical decolorizing agents (oxygen, peroxides, ozone, dichromates, etc.) are used to treat inedible oils, no suitable decolorizer has been found for edible oils. Peracetic acid (IX) should be investigated for possible use in removing excessive color in crude edible oils.



(IX)

Deodorization consists of the removal of the volatile odor constituents from the heated oil under reduced pressure by a current of steam.

Subsequent processing of oil depends upon the use to which the product is to be put. Oils to be used as salad oil or in the preparation of mayonnaise must be "winterized" to remove high-melting triglycerides which might precipitate or break the emulsion of mayonnaise on exposure to low temperatures. During the winterizing process, the oil must be cooled very slowly in order to obtain crystals of stearin large enough to filter without excessive difficulty. Even so, filtration is troublesome because of the rather high viscosity of the cold oil and the soft nature of the stearin crystals. The problem before the industry is to reduce the time required (about 3 days) to winterize the oil. An agent is needed which would induce the formation of large crystals, and thus reduce cooling time or prevent the precipitation of the higher melting triglycerides at low temperatures. Cavanaugh (G-18) has reported a reduction to 1/18 the usual time by winterizing the oil in the extraction solvent.

The reversion (development of beany flavor) of soybean oil has restricted its use to hydrogenated products, such as margarine and shortening (G-19). Upon hydrogenation, a soybean oil becomes

stabilized and reversion is no longer a serious problem. A chemical which would prevent, or effectively retard, the development of the beany flavor, would make it possible to use unhydrogenated soybean oil as a salad oil.

The antioxidants now permitted in food do not have the impressive stabilizing action in vegetable oils they do in lard, perhaps due to the presence of natural inhibitors. More effective antioxidants are therefore needed for use in vegetable oils.

In deep-fat frying, oils are held at high temperatures for long periods of time; this prolonged heating causes undesirable odorants and polymers to be formed. A method for retarding or preventing these effects would be highly desirable.

Oils for use in shortening and margarine must be hardened to a suitable consistency by hydrogenation. Nickel is commonly used as a catalyst for this process, but a selective catalyst should be found which would reduce only particular double bonds of the unsaturated triglycerides, and so prevent the formation of unnatural fatty acids.

Other problems to be solved and improvements to be made in the production of fats and oils are: (1) A better emulsifying agent for mayonnaise is needed to prevent the emulsion from separating even at freezer temperatures; (2) An emulsifying agent for shortening used in preparing cake icing would be valuable; (3) A practical method for the synthesis of triglycerides is being sought.

LITERATURE CITED

G-1. United States Department of Agriculture
1956. Agricultural Statistics.

G-2. United States Department of Agriculture, Bureau of Agricultural Economics
1953. Consumption of food in the United States 1909–1952. Agriculture Handbook No. 62 (Sept. Suppl. Oct. 1955).

G-3. Anon.
1957. Food and feed antioxidants. Jour. Agr. Food Chem. 4, 667.

G-4. May, C. D.
1956. Fats in the diet in relation to arteriosclerosis. Jour. Amer. Med. Assn. **162**, 1468.

G-5. Robe, K.
1957. Newest dietary whipping boy saturated fats? Food Processing, **18**, 21.

G-6. Eagle, E., and H. E. Robinson
1956. Fat cholesterol and arteriosclerosis. Jour. Amer. Oil Chemists Soc. 33, 624.

G-7. Milleville, H. P.
1957. Developments in fat-containing foods. Food Processing, **18** (4), 24.

G-8. Anon.
1956. Unsaturated fatty acids and serum cholesterol levels. Nutrition Rev. **14**, 327.

G-9. Fourt, D. L., C. A. Iverson, C. Jensen, N. E. Fabricius, W. L. Slatter, and G. H. Wilster
1954. Report of Committee on Butter, American Dairy Science Association. Jour. of Dairy Sci. 37, 590.

G-10. Bailey, A. E.
1945. Industrial oil and fat products. Interscience Publishers, Inc., New York.

G-11. Slater, L. E.
1953. Lard scores again. Food Eng. 25, 72.

G-12. Hawley, H. K. and G. W. Holman
1956. Direct interesterification as a new processing tool for lard. Jour. Amer. Oil Chemists Soc. 33, 29.

G-13. Lambou, M. G., N. S. Parker, and H. R. Carns
1956. Effect of maleic hydrazide applied to the cotton plant on the development of free fatty acid in the seeds. Jour. Amer. Oil Chemists Soc. 33, 199.

G-14. Altschul, A. M.
1948. Biological processes of the cottonseed. In Cottonseed and Cottonseed Products, Their Chemistry and Technology, ed. by A. E. Bailey. Interscience Publishers, Inc., New York.
G-15. Andersen, A. J. C.
1953. Refining of oils and fats for edible purposes. Academic Press, Incorporated, New York.
G-16. Cousins, E. R., R. Prachankadee, and S. Bhodhiprasart
1955. Ethanolamine and other amino and hydroxyl-containing compounds in the refining of rice oil. Jour. Amer. Oil Chemists Soc. 32, 561.
G-17. Stillman, R. C.
1955. Bleach and color methods. Jour. Amer. Oil Chemists Soc. 32, 587.
G-18. Cavanaugh, G. C.
1956. New integral process for edible oils. Jour. Amer. Oil Chemists Soc. 33, 528.
G-19. Daubert, B. F., and P. W. O'Connell
1953. Reversion problems in edible fats. Advances in Food Research 4, 185.
G-20. Aaes-Jorgenson, E.
1959. Essential fatty acids as food supplements. Jour. Agr. Food Chem. 7, 246.

Fruits and Vegetables

1. Introduction

Vitamins, particularly ascorbic acid, are the major nutritional contribution of fruits and vegetables to the diet. In 1957, these foods supplied approximately 92 per cent of the ascorbic acid, 75 per cent of the folic acid, and 50 per cent of the Vitamin A consumed, at a cost of some 24 cents of the food dollar (H-1).

Although the total *per capita* consumption of fruits has not changed over the period 1925 to 1957, there was a significant shift from the use of fresh to processed items. During this period the consumption of fresh vegetables remained constant, while the use of processed items increased (Figures H-1, H-2, H-3). Table H-1 shows the level of use of some of these commodities.

California, Florida, and Texas are the principal fruit and vegetable production centers, although some are produced in almost every part of the country.

Table H-1. *Per Capita* Consumption of Fruits and Vegetables in the United States (1957) (H-1).

Fruit	Pounds	Vegetables	Pounds
Total fresh fruit	98.1	Total fresh vegetables	104.6
apples	19.3	tomatoes	12.0
citrus	36.7	cabbage	11.3
bananas	19.2	carrots	6.7
others	42.1	lettuce	20.0
peaches	8.5	onions	11.2
grapes	4.1	celery	8.3
Canned fruit	22.4	Canned vegetables	43.9
Canned juices	12.2	Frozen vegetables	7.5
Dried fruit	3.2	Potatoes	109.0
Frozen fruit and juices	9.0	Melons	25.8

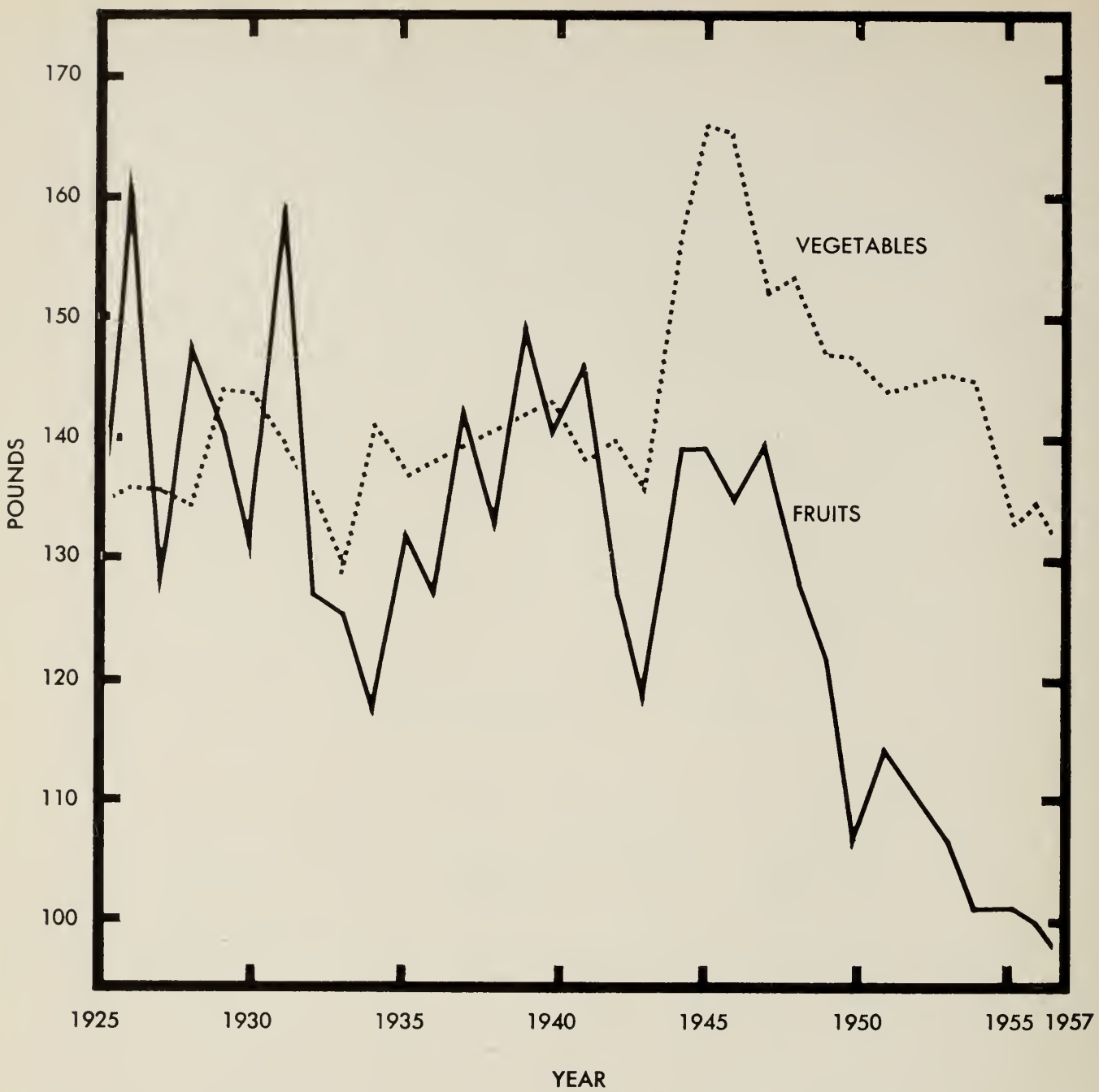
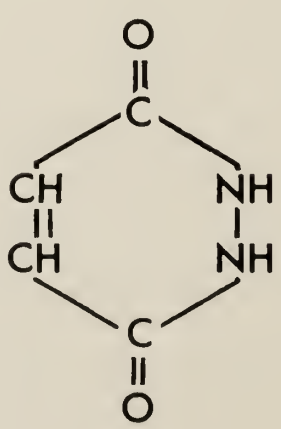


Fig. H-1. U.S. per capita consumption of fresh fruits and vegetables.

2. General problems

Because of the high cost of picking fruits and vegetables manually, and the difficulty in obtaining labor, considerable effort is being devoted to new developments and improvements in mechanical harvesting, which currently involves shaking the trees and catching the fruit in frames. Fruits that can be picked green, when they are less susceptible to bruising, are adaptable to mechanical harvesting; however, only fruits that can be ripened after picking can be handled in this way. Unfortunately, some fruits cannot easily be picked when green. Application of maleic hydrazide (I) to facilitate the removal of green olives has had limited success. The development of a chemical which would make it possible to harvest green fruits mechanically with-



(I)

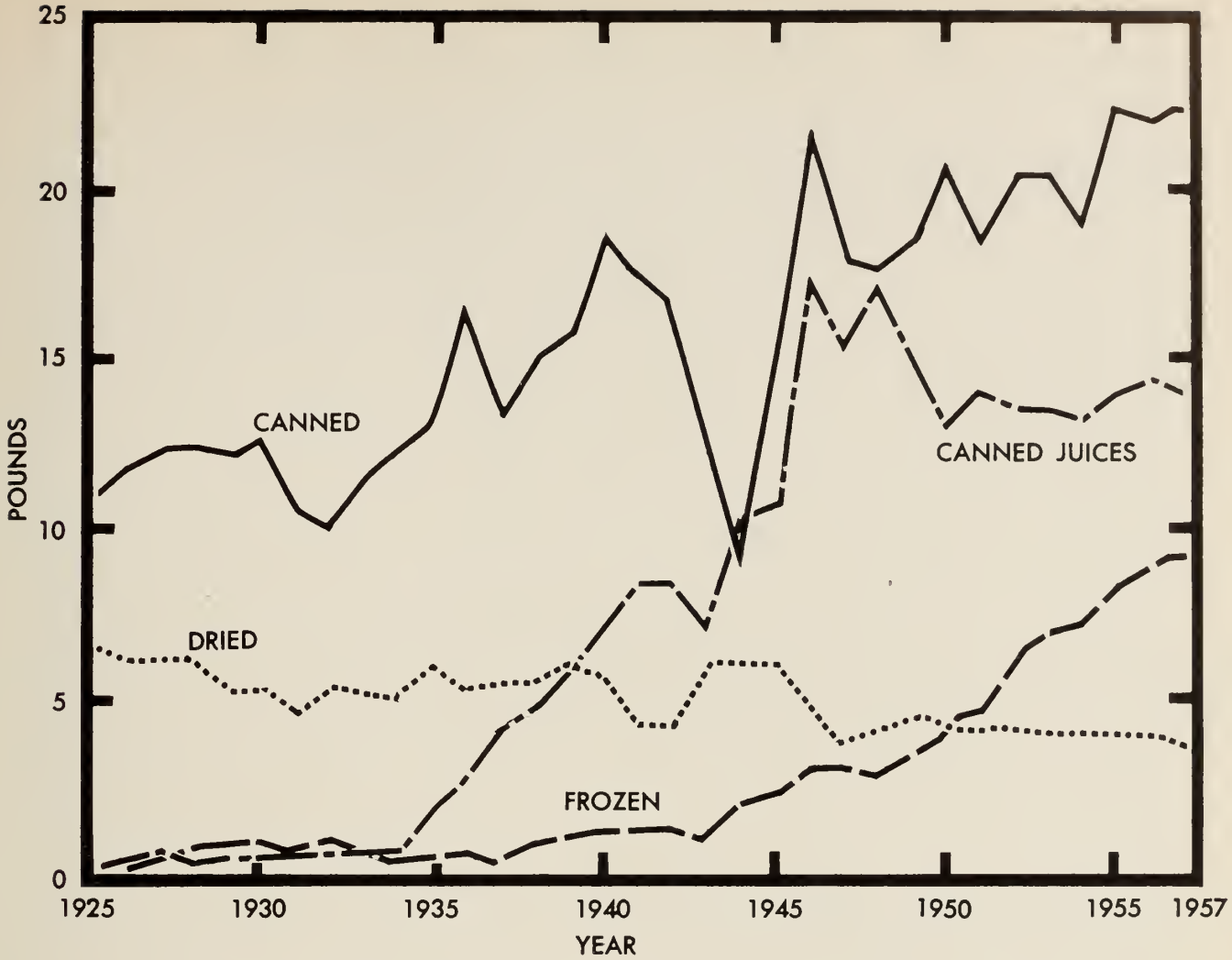


Fig. H-2. U.S. per capita consumption of processed fruits.

out removing the trees' leaves would be of considerable value.

In addition to the usual microbiological and non-enzymatic spoilage problems which plague all of the food industries, fruit and vegetable producers have the unique problem of postharvest changes. After ripening, sprouting during storage, changes in flavor and texture, and many other physiological changes take place after harvest, and harass growers, packers, and shippers alike.

3. Commodity problems

a. Fresh fruits and vegetables

General problems. The principal problems in marketing and handling fresh fruits and vegetables result from physiological breakdown and microbial spoilage. It was estimated from the inspection certificates for fruits and vegetables unloaded in New York City that 300 million dollars' worth was lost annually between 1939 and 1942 (H-2). Some examples of the losses in the various commodities are summarized in Table H-2.

Since these data are almost 20 years old (more recent information is not available), undoubtedly improvements made since then have considerably decreased these losses.

Some specific problems. While adequate refrigeration reduces the amount of bacterial spoilage, exposure to low temperatures causes injuries to a number of fresh fruits and vegetables. Thus, to control the growth of microorganisms, a number of chemicals are applied prior to, or during, storage and shipping. These agents may be applied directly to the product, or used to fumigate the box-

Fig. H-3. U.S. per capita consumption of processed vegetables.

cars after they have been filled with the produce. The chemicals currently available do not offer the complete solution to microbial spoilage, since extensive losses still occur. Probably the most striking example of this is in fresh strawberries, where it is rare to find a basket marketed through commercial channels that does not show some damage.

The use of detergents to clean fruits and vegetables, and to lower the bacterial load, is severely limited because of the FDA ruling that no residue of such chemicals on food items is permissible. Consequently, if chemicals are to be used to solve these problems, they must leave non-toxic residues or completely decompose before consumption.

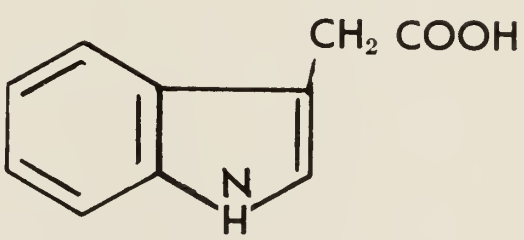
Table H-2. Annual Fresh Food Losses in the United States from 1939 to 1942.

Commodity	Percentage lost	Type of spoilage
Apples	20.9	Blue mold and bull's-eye rot, scald, and internal breakdown
Grapefruit	12.8	Blue mold and stem end rot
Grapes	9.0	Gray mold and Rhizopus rot
Oranges	15.3	Blue mold and stem end rot
Strawberries	25.0	Gray mold and Rhizopus rot
Cabbage	11.6	Bacterial soft rot, watery soft rot, Alternaria leaf spot, black rot, and gray mold
Celery	18.6	Watery soft rot, bacterial soft rot, and blackheart (phsyiological)
Lettuce	24.5	Tipburn (physiological) and bacterial soft rot
Onions	20.0	Bacterial soft rot, gray mold, black rot, and smudge
Peppers	25.3	Rhizopus rot, bacterial soft rot, gray mold, anthracnose, scald, and freezing
Potatoes	15.5	Bacterial soft rot, blackheart (physiological) and freezing
Tomatoes	21.6	Bacterial soft rot, Rhizopus rot, Alternaria rot, Phoma rot, late blight, and other decays, and by freezing and chilling
Watermelons	15.0	Anthracnose, stem end rot, and other decays

During the past few years, biphenyl has been used quite extensively on the wrappers of oranges to retard the development of molds, but objections have been raised to the undesirable odor imparted to the fruit, and a more satisfactory chemical is needed. Another problem encountered in fresh oranges is the redevelopment of the green color while still on the trees; ethylene is not an effective remedy.

It is well known that fresh corn and many other produce items lose flavor very rapidly after picking. This has been attributed partly to the loss in sugar through respiration and partly to the conversion of sugar to starch. It would be highly desirable to retard this deterioration and to retain more of the fresh quality. In potatoes, too, it would be of value to control the reaction between sugar and starch at some ideal ratio.

Sprouting during storage is a problem to all fresh fruit and vegetable consumers. Within the last 10 years a number of chemicals have been found that inhibit potato sprouting. The application of maleic hydrazide to the foliage approximately 10 weeks before harvest provides adequate control, and a number of chemicals, including indoleacetic acid (II) and amyl alcohol (III), have been applied directly to tubers for this purpose (H-3). Inhibiting the sprouting of potatoes and onions appears to be one of the more successful results of ionizing radiation.



(II)

$CH_3CH_2CH_2CH_2CH_2OH$

(III)

Sprouting is only one aspect of the much broader problem of postharvest physiology. Fruits and vegetables generally continue to live and develop after harvest, but this is not always the case. For instance, freestone peaches are picked ripe, which severely limits the period during which they may be shipped or processed. On the other hand, clingstone peaches may be after-ripened, which represents a great advantage to both the producer and the canner. Methods by which ripening could be speeded or slowed at will would be of wide application, but their development may well have to await further knowledge about fruit physiology and biochemistry.

Very little is known about the extent to which nutrients are lost from fresh fruits and vegetables, or from those which must be picked green for purposes of distant marketing, between harvest and consumption. Research is needed to determine if there is loss, and to what extent. And if it should be shown that appreciable nutrient losses do occur, then methods will be needed for curbing them.

b. Processed fruits and vegetables

General problems. A load of fruit or vegetables is frequently held at the processing plant for as long as a day before being processed. During this time, foods such as asparagus, shelled peas, and spinach undergo respiration so rapidly that the temperature rises sufficiently to cause considerable deterioration. A chemical that could be applied to the crop before or during harvesting, and which could retard respiration, would certainly upgrade the quality of the processed product.

To reduce costs, some items are transported in bulk in water between the farm and processing plant, making it possible for the processor to handle items such as peas and peaches with a pump. At present, chlorine is added to the water to retard microbial growth. At effective concentrations, however, chlorine imparts its odor to the product, and also has an undesirable bleaching effect. A more suitable agent is needed.

Insects, particularly fruit flies and aphids, are a continual hazard to processors. A detergent or some other agent is being sought which, when added to the wash water, would effectively remove these pests, especially from items such as broccoli. Closely related to this is the need for investigation of the effectiveness of water-softening agents and detergents (H-4) in removing pesticides during processing.

Canned foods. Sealed containers treated by heat processing are still the most widely used method of extended preservation. The great convenience of canned items lies in their stability at room temperatures, and the highly acceptable canned fruit items have not met competition from the frozen field, as have many of the canned vegetables. One of the most serious problems in canning vegetables is that the heat treatment required by these nonacid foods to obtain sterility leads to excessive changes in both flavor and texture. Many people have become accustomed to some canned vegetables (peas, for example), but, in general, it is desirable to find a way to eliminate the over-cooked taste and soft texture brought about by the usual canning procedures. The amount of heat treatment necessary for canned foods might be reduced by some method affecting spore germination, as discussed previously (see the section on Canned Meats).

At the completion of the heat treatment, the cans of food are cooled. Chlorine is added to the cooling water to sterilize it in the event that any should be drawn into the cans inadvertently. One serious disadvantage of the use of chlorine is the corrosive effect it has on the cans, and a cheap noncorrosive bactericide adaptable for use in the cooling water is needed.

At present, sodium hydroxide is quite an effective fruit peeling aid. To compete with its low cost would be difficult, but an agent that would remove only the skin of the fruit might be competitive by reducing peeling losses and permitting greater retention of flavor.

Each commodity presents its own characteristic problems: among them are the ragged texture of canned freestone peaches, the hard texture and lack of flavor of cling peaches, and the darkening of asparagus and also the brine of ripe green olives when the cans have been opened and the contents exposed to air.

Frozen fruits and vegetables. One of the principal considerations in the freezing of fruits and vegetables is the effect on texture. Textural changes are brought about by the puncturing of cell walls by ice crystals, dehydration of cells, and destruction of colloidal complexes within the cell. In general, these changes are not objectionable in frozen vegetables, since cooking has the same effect. But the fact that freezing brings about certain textural changes makes it somewhat unsatisfactory for some foods, such as strawberries, which become mushy upon thawing, or wholly unsuitable for other foods, such as lettuce and celery, whose appeal lies principally in their crispness.

Excessive amounts of liquid may be lost through "weepage"; the development of a chemical that would permit retention of the textural properties of fresh fruit throughout freezing and thawing should make many frozen items much more acceptable.

Since frozen fruits are generally not blanched, enzymatic action continues through the period of frozen storage and may lead to several undesirable changes. An example is the darkening of frozen peaches to which no ascorbic acid has been added. Occasionally, insufficiently blanched frozen vegetables develop hay-like flavors through the action of enzymes.

Part of the production line of the Hawaiian Pineapple Company plant in San Jose. (Dole photo.)

The consumption of frozen concentrated orange juice has skyrocketed since its introduction some 10 years ago. The principal difficulty with this product is the settling of the suspended material, brought about by the action of pectic enzymes (H-5). To retain the stability of orange juice, processors have resorted to heating the concentrate to inactivate these enzymes, but in so doing they have sacrificed a certain amount of flavor. The application of an additive that would nullify the action of pectic enzymes, or inactivate them, would result in an improved product by eliminating the need for heat treatment.

Another problem encountered in the processing of orange juice concentrate is the development in the concentrator of organisms that lead to off-flavors ("buttermilk flavor") (H-6), as a result of which the concentrating equipment must be shut down and cleaned every few days. Another method of adequately controlling the microorganisms could lead to more economical processing of the concentrate.

Fluctuating temperatures during stor-

age of frozen vegetables tend to accelerate dehydration, which in turn leads to formation of undesirable color and toughening of texture. Packing frozen vegetables in brine would alleviate this problem, but added refrigeration and transportation costs make this procedure impractical. A method should be devised to prevent the dehydration of these products.

The freezing preservation of fruits and vegetables is obviously by no means perfect. Many items may be successfully preserved by freezing, but others, as described above, present problems which may prove insurmountable within the limits set by economic necessity.

Pickles. It has recently been estimated that approximately a million dollars' worth of salt stock cucumbers are lost annually because of the action of pectinolytic and cellulolytic enzymes (H-7, H-8). These enzymes originate from microorganisms which grow in the wilted cucumber flowers, and at present there is no practical method of removing these flowers. Softening of the cucumber also results from the growth of certain species of *Bacillus* in the initial brine at low salt concentration. The suggested method for reducing this loss is to drain the initial solution from the cucumbers after 36 to 48 hours of immersion, but it would be valuable to find an agent which could be added to the brine, and which would both stop the action of enzymes causing softening, and prevent the growth of spoilage organisms.

During the production of fermented items, such as pickles, it would be desirable to restrict microbial growth to beneficial organisms only. To develop a chemical for this purpose, fundamental studies on the nutritional requirements of these organisms will be necessary. Sorbic acid has been reported to reduce spoilage caused by yeast and molds (H-9, H-10), but it may also impart a gray color to the pickles, and at economic concentrations it is not consistent in retarding spoilage. Investigation should be made into the practicability of using some of the more selective antibiotics for this purpose.

Appearance is an important factor in the sale of pickles, which are usually packed in glass containers. Color fading occurs during pasteurization and continues more slowly during storage. Another problem is the development of "sack bruises" (unsightly brown scratches caused when the cucumbers are handled in sacks), which begin to appear 8 to 10 months after the injury has occurred. During pasteurization pickles also lose flavor, and some method for retaining flavor is needed. In fact, an agent might be developed which would eliminate the need for pasteurization altogether.

Another problem in this area is the instability of pickle products to light. The extent to which ordinary artificial lighting in food stores contributes to the difficulty has not been determined and may. in fact, have much more extensive effects on food products than we realize. Colored containers to screen out the harmful radiation may be the answer, while the use of chemical energy absorbers presents another untested approach.

Dried fruits and vegetables. This group is represented by two major commodities, prunes and raisins, which are currently either sun-dried or dried in a dehydrator (with heated air). When preservation of the original color is desirable, as in golden raisins, dried apricots, and peaches, sulfur dioxide is applied prior to drying. The recent annual *per capita* consumption of approximately 4 pounds of dried fruit may seem to be very small. Considering, however. that approximately two-thirds to three-quarters of the fresh fruit weight is lost during drying, this is comparable to the *per capita* consumption of fresh bananas or apples.

During the latter stages of maturation, and during sun drying, it is almost im-

possible to avoid fruit flies. (*Drosophila*). Large infestations during this period lead to quantities of insect fragments in the final product, with the result that it cannot then be sold for food use. Since it is impractical, at present, to eliminate the flies from the field, insect contamination may be reduced through the use of repellents. Some work along these lines is being carried out, but no effective repellent has yet been found. Fruit flies are also a serious problem in some fresh fruits and vegetables, and in the canning and wine industries.

A difficulty met with in sun-dried fruits is the growth of mold, caused either by unseasonal rains or by farm storage during wet weather. Excessive amounts of mold growth result in lower grading or condemnation.

Approximately 40 per cent of the dried raisins are processed during the harvest season, the remainder throughout the year. Raisins stored so that they can be processed over the entire year are liable to infestation by insects and must be fumigated from time to time. Again, an insect repellent would be useful as a preventive measure.

Dried fruits could be more widely used in dry cereals and baking mixes if an efficient moisture barrier were to be applied either to the cereals and mixes or to the fruits themselves. The higher moisture content of dried fruits generally leads to loss of crispness, and particularly has an adverse effect on cookie mixes.

One objection to applying sulfur dioxide to dried fruits is its undesirable effect on flavor. A suitable agent that has little or no flavor of its own and will perform all the functions of sulfur dioxide could certainly be utilized by the industry.

Recently, such convenience items as dehydrated potato granules (for preparing mashed potatoes) and powdered pea and tomato soups, and orange juice have become available. The development of these and other new dehydrated items, along with improvements in present products, could reverse the decline in the utilization of dried commodities. However, the reconstitution of dried foods—returning them to their original size, flavor, and texture—is a serious and complex problem which faces the industry and which deserves serious attention in terms of research.

LITERATURE CITED

H-1. United States Department of Agriculture, Bureau of Agricultural Economics
1953. Consumption of food in the United States 1909–1952. Agriculture Handbook No. 62 (Sept. Suppl. July 1958).

H-2. United States Department of Agriculture, Agriculture Research Service
1954. Losses in Agriculture. Publication ARS-20-1, June (Mimeographed).

H-3. Burton, W. G.
1957. The dormancy and sprouting of potatoes. Food Sci. Abs. 29, 1.

H-4. Brekke, J. E., C. C. Nimmo, H. A. Swenson, C. E. Samuels, and J. R. Brock
1953. Studies on removal of thrips from cane berries intended for processing. United States Department of Agriculture, Bureau of Agriculture and Industrial Chemistry, Agr. Res. Admin., AIC-353, Feb.

H-5. Guyer, R. B., W. M. Miller, O. W. Bissett, and M. K. Veldhuis
1956. Stability of frozen concentrated orange juice. Food Tech. **10**, 10.

H-6. Berry, J. M., L. D. Witter, and J. F. Folinazzo
1956. Growth characteristics of spoilage organisms, in orange juice concentrate. Food Tech. **10**, 553.

H-7. United States Department of Agriculture.
1957. How to control pickle softening due to mold growth on withered flower. Agr. Res. 5 (9), 9.

H-8. Demain, A. L., and H. J. Phaff
1957. Softening of cucumbers during curing. Jour. Agr. Food Chem. 5, 61.
H-9. Phillips, G. F., and J. O. Mundt
1950. Sorbic acid as inhibitor of scum yeast in cucumber fermentation. Food Tech. 4, 291.
H-10. Costilow, R. N., W. E. Ferguson, and S. Ray
1955. Sorbic acid as a selective agent in cucumber fermentation. Applied Microbiology, 3 (6). 341.

Cereals and Cereal Products

1. Introduction

The general trends in the *per capita* consumption of cereal products between 1925 and 1957 are shown in Figures I-1 and I-2. The decline in the consumption of cereal products (with the exception of rice and wheat cereal) is considered by some members of the industry as its most serious problem (I-1). The more recent decline may be attributed to our high land values and the subsequent shift from starchy foods, such as cereal products and potatoes, to meat and poultry products. Interestingly enough the decrease in carbohydrate consumption since 1925 has not been accompanied by an increase in consumption of protein or fats, but rather by an over-all falling off in caloric intake (Figure I-3).

On the basis of major food groups (meat, poultry and fish, dairy products, fats and oils, etc.), cereals still supply the largest proportion of food energy, but only by a small margin. In 1957, cereal products supplied 21.0 per cent of the food energy, while fats and oils commodities supplied 19.9 per cent (I-2); a substantial decline from the 1909 to 1913 period, when cereal products contributed 37.2 per cent of the food energy in the American diet. In 1957, cereals also provided a major portion of the thiamine consumed (31.7 per cent), and considerable amounts of protein (19.5 per cent), iron (23.7 per cent), and niacin (23.1 per cent).

2. General problems

a. Storage problems

Losses during the storage of cereal grains result from a number of causes. Between 1942 and 1951 the estimated annual loss during farm storage of cereal grains (exclusive of loss due to insects) was approximately 2 billion dollars (I-3).

The most serious losses are those due to heat damage; this has been primarily attributed to the heat evolved during the growth of molds in cereal grains whose moisture level is above a critical value. The heat from the respiration of the grain and from metabolic activity of insects, if the grain is infested, can also contribute to heat damage during storage.

Investigation of the possible chemical control of molds to prevent the spontaneous heating of moist grains has been reviewed by Milner and Geddes (I-4). Although a number of chemicals have been tested, no suitable agent has yet been found which would control the growth of molds and preserve the quality of cereal grain. Milner and Geddes pointed out the usefulness of ethylene oxide and methyl bromide against insects; however, its fungistatic proper-

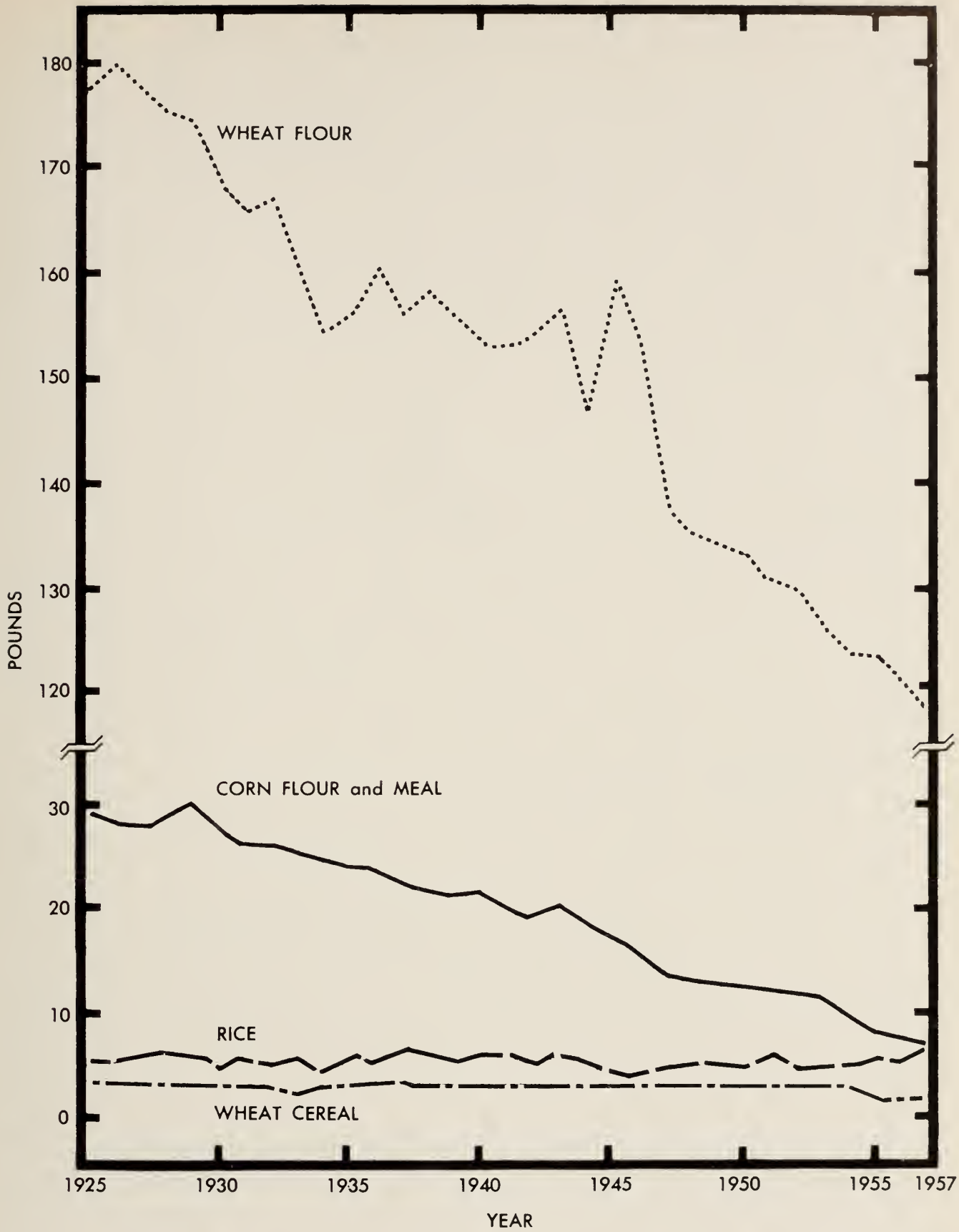


Fig. I-1. U.S. per capita consumption of cereal products.

ties have not been determined. An acceptable chemical which would control heating, even for a short period of time, would be of considerable value. Such a material would be especially useful in areas where rain occurs during the harvest season. since it would provide control of mold growth until the grain could be dried to a safe level of moisture. Because a considerable proportion of the losses occurs at the

Fig. I-2. U.S. per capita consumption of cereal products.

farm level, a simple method of application would be desirable.

Yen and co-workers (I-5) recently have published on the use of gamma radiation for elimination of the usual respiratory phenomena of grain undergoing heating. In a following report, Milner and Yen (I-6) showed that bread made from grain irradiated at the lower levels suffered little loss in quality. In fact, improvements in bread quality were noticed at the lowest level of irradiation. Gamma radiation is probably not the best answer to the problem of heat deteriora-

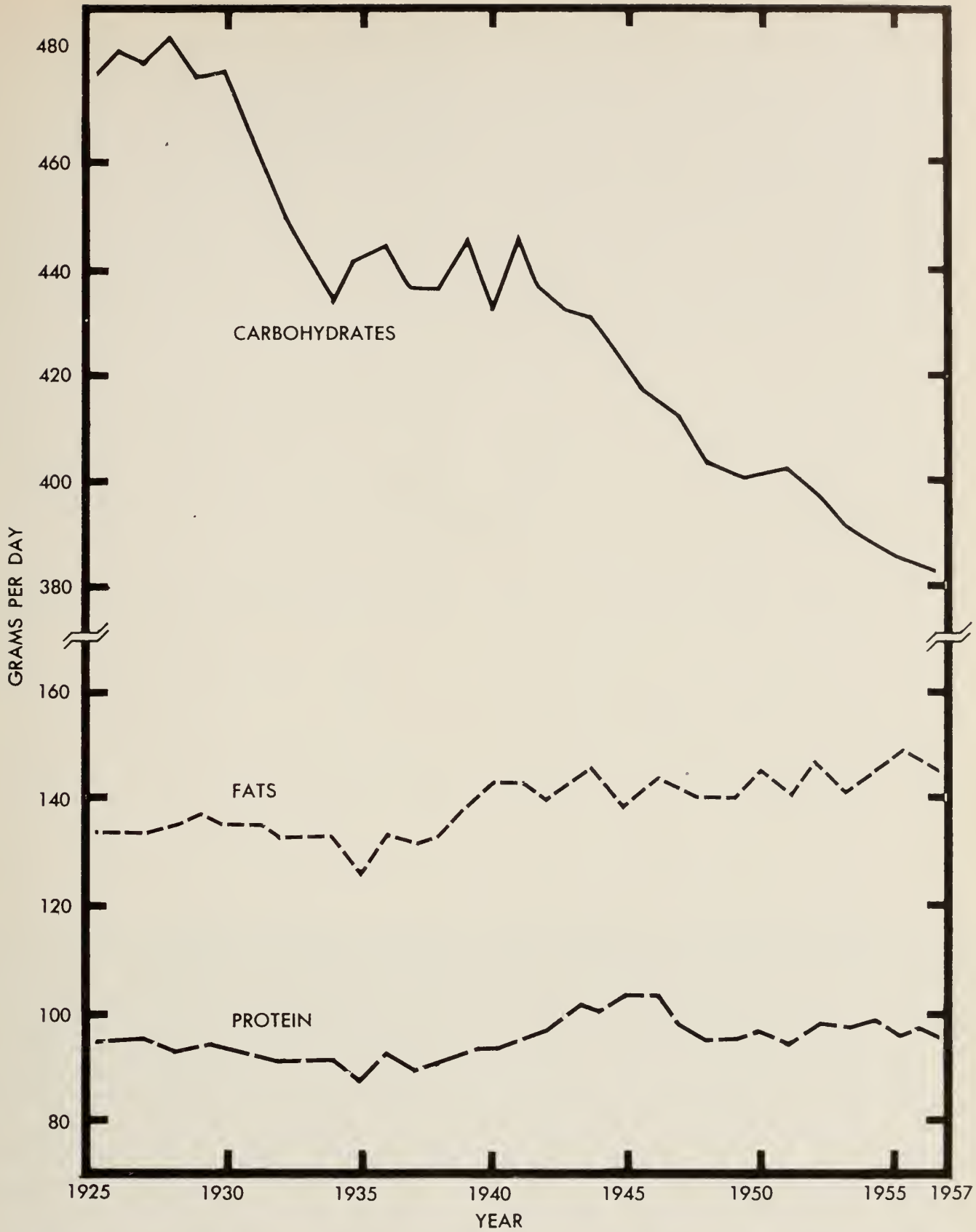


Fig. I-3. Nutrients available for U.S. consumption per capita per day.

tion in grain, however, since most of the losses occur during farm storage, and the use of gamma radiation at the farm level cannot be considered practical there.

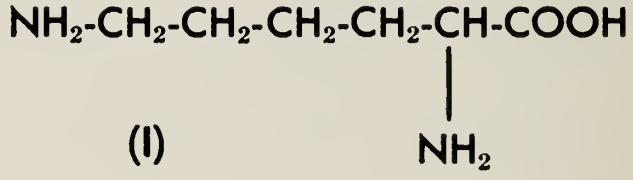
Losses incurred from insect and rodent infestation (during grain storage), either by direct consumption or by contamination, are extremely great. Annual losses due to insects alone have been estimated at between 500 and 600 million dollars (I-7, I-8). Since much of this is caused by contamination during farm storage,

there appears to be a need for an insect repellent which will be non-toxic or removable during processing, and which will not have any deleterious effect on the final product.

Several effective fumigants are presently available, but they may prove to be impractical for farm use because the loose construction of storage bins makes effective fumigation difficult. Even if storage bins could be fumigated, reinfestation probably would easily occur.

b. Nutritional problems

The low level of the essential amino acid lysine (I) in the protein of wheat, rye, and whole oats has been recognized for some time (I-9). The recent commercial production of amino acids has stimulated efforts to increase the protein value of some foods by the addition of such compounds. In some localities bread, cookies, and breakfast cereal have already appeared on the market with added lysine (I-10). Not only do inadequate quantities of an essential amino acid lead to nutritional deficiencies, but excessive amounts of a single amino acid can lead to protein imbalance, amino acid toxicity, and amino acid antagonism (I-11). Although the toxic effects of amino acid imbalance and antagonism are most readily shown in animals fed on low protein diets, these effects can occur even with adequate levels of protein. To obtain the maximum nutritional value, a proper ratio as well as a minimal amount of amino acids are needed (I-12). Thus the minimal requirements of an amino acid cannot be met by increasing the intake of a deficient protein. Although no single protein has been determined to be "ideal," human milk protein or egg protein may be considered to have the most desirable composition.



(I)

A very interesting policy change on the supplementation of foods with amino acids was announced recently by the

Rodents, an ever-present problem in grain storage, make their presence known by torn sacks and droppings. (Photo by U.S. Public Health Service.)

Food and Nutrition Board, National Research Council of the National Academy of Science. In 1955 the Board stated that "with the present quantity and quality of protein available in the United States there appears to be no need for amino acid supplementation of foods in this country." A recent statement by the Board suggests that now the possibility of using amino acids to supplement dietary deficiencies "is an attractive one" (I-13). The Board recognized the potential value of proper supplementation with amino acids, and the necessity for intensive study of this problem.

There are still many questions that must be answered before any wide-scale supplementation of our present food could be adopted. If it could be shown that amino acid supplementation would benefit any segment of our population, then this supplementation would be accepted, just as vitamin supplementation has been accepted in bread, flour, milk, etc. Supplementation with amino acids would become a necessity if our population should ever become largely dependent on deficient proteins such as those found in cereals, a situation which might arise during wartime.

3. Commodity problems

a. Wheat and wheat flour

"Sick wheat" is a deterioration which occurs most often when wheat is stored in large quantities for a considerable length of time (I-4). It can occur below the critical moisture level and with no detectable heating. The primary commercial criterion for "sick wheat" is the discoloration of the embryo. While a number of reasons have been suggested to account for this breakdown, its exact nature is still unknown.

The following is a very brief description of the processes involved in the production of flour.

Cleaning: The removal of straw, dirt, smutted wheat, other seeds, etc.

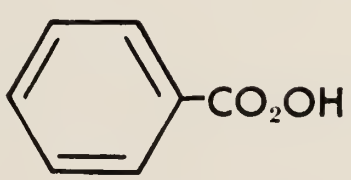
Tempering or conditioning: The addition of water to whole grain, followed by a short holding period to obtain maximum toughening of the bran for better separation from endosperm.

Milling: The gradual separation of endosperm from bran by repeated passage between rollers. After each passage, the material is separated according to particle size (by sifting or purification) into various streams for further reduction, or into product bins. Detailed descriptions of flour milling may be found in the literature (I-14, I-15).

A constant goal of flour millers is to obtain higher yields of flour without loss in flour quality. Wheat grain consists of approximately 84 per cent endosperm, 14 per cent bran, and 2 per cent germ. Theoretically, one could obtain all the endosperm as flour, but in practice flour yield usually ranges between 70 and 74 per cent. The loss is due to particles of endosperm which adhere to the bran. It is conceivable that some chemicals might be found which, when added to the tempering water, would facilitate better separation of endosperm from bran.

The millers have long known that freshly milled flour could be improved both in color and in baking qualities by storage. Addition of certain chemicals called maturing and bleaching agents were found in later years to produce the same effects as storage.

Usually both maturing and bleaching agents are classified under one category since, in some cases, a single agent can perform both functions. Although a number of these are allowed under FDA standards of identity, chlorine dioxide (Dyox) and benzoyl peroxide (I)



(I)

(Novadelox) are used exclusively during production of bread flour in the United States (I-16). Potassium bromate is also widely used as maturing agent, but its action occurs almost entirely in the dough stage. For cake flour chlorine gas produces effects not obtainable by any other agent.

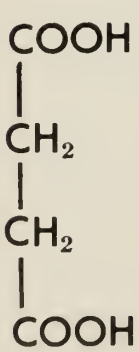
There are members of the milling industry who are not completely satisfied with the maturing agents presently available, and perhaps more acceptable chemicals can be found. Succinic acid (II) is said to be one of the most powerful maturing agents known, but it is too expensive for general use (I-15). Ascorbic acid (III) is another maturing agent which falls in this category, and in some foreign countries this compound is the only maturing agent permitted. If the cost of these chemicals could be substantially reduced, their use might be well worth further investigation.

Another approach to flour whitening might be the use of an optical bleach similar to those employed in soaps and detergents. Several coumarin (IV) derivatives have been reported to be suitable for this purpose in sugar and flour (I-17). These compounds were reported to be nontoxic at the levels used, but this claim might be open to question because of the recently revealed toxicity of coumarin itself.

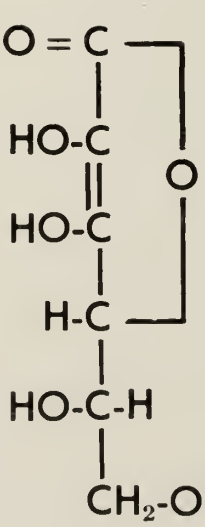
There has been some question as to the necessity for bleaching flour. At the consumer level, the elimination of bleaching of bread flour might hardly be noticed, at least with the present type of flour.

Insects continue to be as much of a problem in the storage and transportation of flour as in the storage of whole grain. Fumigation by methyl bromide effectively controls insects, but in cases where the product is fumigated a number of times between harvest and consumption, the residual bromide concentration built up by repeated application might reach a dangerous level. Furthermore, repeated application of methyl bromide to flour has been said to impart a "mousey" odor to the bread.

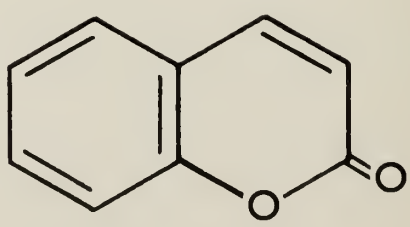
Under the provisions of FDA Standards of Identity, a malt preparation may be added by the millers to compensate for any natural deficiency of diastatic or proteolytic enzymes in flour. The diastatic enzymes serve to produce fermentable sugars, good loaf volume, grain, and texture, as well as good crust color. Proteolytic enzymes soften and mellow the stronger wheat flour, and improve consistency of the dough. Fungal enzyme preparations from *Aspergillus oryzae* may not be added to flour by the millers under the Standards of Identity, but may be added during the manufacture of bread and rolls (I-18). The advantage of



(II)



(III)



(IV)

View inside the Los Angeles plant of Fairfax Bread Company. (Safeway News photo.)

the fungal enzyme preparation is that the amounts of diastatic and proteolytic enzymes may be varied according to need.

With the scarcity of good quality bread flour, there appears to be a need for some chemical which, when added to weak flour, would impart product quality and dough characteristics equivalent to bread made from the strong flour.

b. Baked products

Bread. Only four basic ingredients are required for manufacturing bread: flour, water, salt, and yeast. Additional ingredients are added to improve bread quality from the standpoint of color, texture, nutritional value, etc. In U.S. typical bread formula consists of 100 parts flour, 64 parts water, 2 parts salt, 6 parts sugar, 6 parts nonfat milk solids, 4 parts shortening, and 0.2 to 0.5 parts dough conditioners.

Bread is usually made by one of two procedures: the straight dough method, in which all the ingredients are mixed in one operation, and the sponge and dough method, which is preferred by bakers because of the savings in yeast, improved bread volume and texture, and greater flexibility in baking schedules. The latter method consists of two mixing steps: About 50 to 70 per cent of the flour, all the yeast and yeast food, and sufficient water, are mixed together and allowed to rise; when this sponge is sufficiently developed, the remainder of the ingredients are added to form the dough. Several bakeries have recently installed a continuous breadmaking process (I-19) which has cut the elapsed time from mixing to pan for proofing and baking to about 2 minutes.

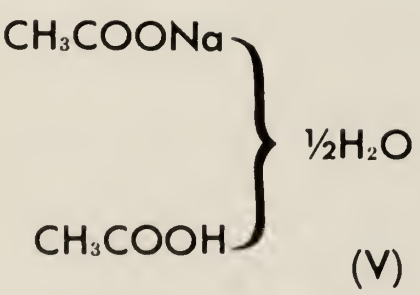
The use of silicone pan glaze has eliminated the need to grease each pan before adding the dough, but since a small amount of silicone glaze is lost to each loaf of bread, the glaze must be reapplied from time to time. The development of a more durable glaze would be useful to the baking industry.

A rather subtle but important problem in modern bread manufacture is the lack of flavor in the present commercial product. Because the large commercial bakers operate in such a way that bread is several hours old by the time it reaches the retailers' shelves, flavor and aroma appeal deteriorate appreciably before it reaches the consumer (I-1). Several investigations are under way to determine the aromatic constituents of bread

(I-20); once described chemically, they could be added to bread to maintain or enhance aroma and flavor.

Staling is one of the most serious problems in bread products. Approximately 6 per cent of the bread produced during 1953 was returned as "old bread" (I-21). A more descriptive expression of the losses due to staling in 1952 was that it was "an amount adequate to furnish bread for a city the size of Philadelphia for an entire year" (I-22). It is generally accepted that crust staling is due to absorption of moisture, and Bechtel and co-workers (I-23) have shown that flavor change is associated with the crust. Crumb staling, however, is a more complex process, and because of the various criteria used to measure staling, there is no agreement on the quantitative definition of this phenomenon. Even though a considerable amount of work has been done on the staling of bread, there is still much to be learned. Bechtel (I-21) has reviewed the research on the subject. At the present time it is difficult to conceive of an economical control feasible to all the deteriorative factors in bread staling by chemicals.

Molding of bread is not an important problem because of its relatively short shelf time and the addition of fungistatic agents, such as propionates and sodium diacetate ("Dykon") (V) (I-24). Molding does become important in brown-and-serve rolls because of the longer shelf life needed for these products, and there is need for fungistatic agents more effective than those now being added. Since brown-and-serve rolls are heated before eating, perhaps a chemical can be found which would break down to nontoxic products when heated, as do certain antibiotics used on poultry.



(V)

Cream-filled bakery products. Food poisoning as the result of the growth of toxic organisms in cream-filled bakery products continues to be an important public health problem. According to Feig (I-25), approximately 35 per cent of the *Micrococcus* (*Staphylococcus*) outbreaks are caused by bakery products, and in some states the sale of cream-filled products is prohibited during the summer months. There is apparently no satisfactory method for control of these organisms in the usual commercial outlets. The development of a nontoxic chemical to control the growth of food-poisoning organisms would be of value.

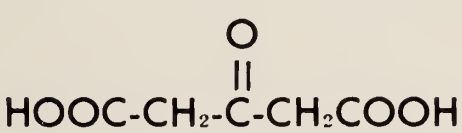
Cakes. Mold spoilage is not as serious a problem in cake merchandising as in bread or rolls. (I-26). Although the pH of cakes is conducive to mold growth, the higher sugar content, lower moisture, and use of icing minimize the extent of molding. However, mold does become a serious problem when cakes are on sale for an extended period of time, particularly during the summer months; fruit cakes are among those with an extended merchandising period. Experiments have shown that sorbic acid is four times more effective than propionates for use in cakes, and that it imparts less foreign flavor.

Chemical leavening agents. The use of chemicals to leaven baked products was proposed over a century ago by Liebig, but his suggestion was not adopted until sodium bicarbonate became available at a low cost through the Solvay process. The leavening action is produced by the interaction of a "baking acid" on sodium bicarbonate in the dough or batter. Cream of tartar, monocalcium phosphate, sodium aluminum sulfate, and sodium acid pyrophosphate are the "baking acids" available in commercial quantities. Usually, combinations of two or

more of these compounds are used to produce the desired effect, and perhaps a more economical or useful acid could be found or developed. The action of the various "baking acids" in different media is discussed by Brackman (I-27).

Although a number of developments have been made in the field of leavening agents, there are still many problems to be solved (I-28). One disadvantage of the use of sodium acid pyrophosphate is that a small residual quantity of this material in cakes or doughnuts imparts a bitter or metallic aftertaste. Also, variability in the action of leavening occurs with different flours; granulation, age, seasonal variations, and other factors all seem to play an important part in the leavening of baked products.

According to Logue (I-29), an ideal leavening agent would be one which would totally decompose into a gas, leaven the dough, and leave no residue. Acetone dicarboxylic acid (VI) has been proposed as one such agent, but its cost has been too high for commercial use. A leavening agent which would be activated by heat rather than by the action of hydrogen ions would be especially helpful in refrigerated and frozen batters and doughs. One of the requirements for such a chemical would be a decomposition point below 85°C., since the coagulation of the gel structure occurs at approximately this temperature. A leavening agent recently has been reported which is triggered by heat (I-30). It is a stabilized form of dicalcium phosphate; the triggering action is still dependent on the release of hydrogen ions. Bicarbonate ions are generally relied upon as a source of CO_2.



(VI)

c. Breakfast cereal

Stuckey (I-31) has stated that the results of his tests indicate a problem of rancidity in some dry cereal products even though they have extremely low fat content. Such prepared breakfast cereals therefore have relatively short shelf life with respect to the nutty odor and flavor normally associated with these products. Some method of preventing deterioration would be highly desirable.

d. Macaroni products

The steps involved in the production of macaroni products consist of mixing the semolina and/or flour with water and the optional ingredients listed in the Standards of Identity, kneading to remove any granular structure in the dough, extruding into desired shape, cutting to proper length, and drying. Detailed information concerning the production of these commodities is in the literature (I-15, I-32).

Color is a very important factor in the quality of macaroni products, especially in the United States. There has been considerable work done in developing wheat with desirable coloring for use in macaroni products. Another approach to the problem could be through the addition of coloring agents during processing. Since carotenes are the primary coloring constituent of durum wheat, the synthetic β-carotene now available might be used, with the advantage of producing uniformly colored products. Actually, the present Standards of Identity on macaroni products do not allow the use of coloring matter, but some yellow is imparted to the enriched macaroni from the added vitamin concentrate.

Drying is probably the most critical operation in the production of macaroni products. Checking or cracking is caused by too rapid drying, and is a result of the differential rates of drying between the surface and the center of the macaroni, since the coefficient of expansion with respect to moisture content is large. To obtain a product reasonably free of

checking, dehydration is carried out in successive drying and equilibrating (sweating) steps. Lecithin has been proposed as a plasticizer for macaroni, and perhaps other plasticizers might be found that could be added to foods. Molding or souring sometimes occurs in the product because of the long periods required for drying. They also occur along the sides of the drier where wet products may touch, and on particles that drop in the driers, and make frequent shut-downs for cleaning necessary.

Another problem met with in macaroni products, which might be solved by the addition of a surfactant, is the presence of specks of semolina. Insects also present a problem at every stage from production to home storage.

e. Rice

The storage of rice presents a special problem not encountered in other cereal grains. It is harvested at relatively high moisture content, and thus must be dried artificially to prevent souring before it is put into extended storage. The operation consists of repeated drying alternating with resting periods (approximately 1 day), since rapid removal of moisture or exposure to high temperatures leads to checking or cracking of the kernels. Souring, although it can be controlled by sufficient lowering of the moisture content below a critical level, is still a problem in rice storage, especially when rains occur during the harvest season. The development of a chemical which would retard souring even for a short period of time would be of considerable value.

Herewith a brief description of the operations involved in milling of white rice (I-15):

Cleaning: The removal of straw, dirt, watergrass seed, etc.

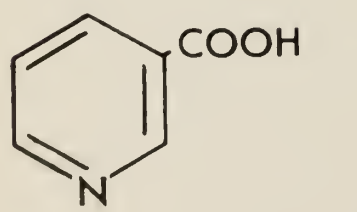
Shelling: The removal of hull from the grain.

Scouring: The removal of bran layers and germ from hulled rice.

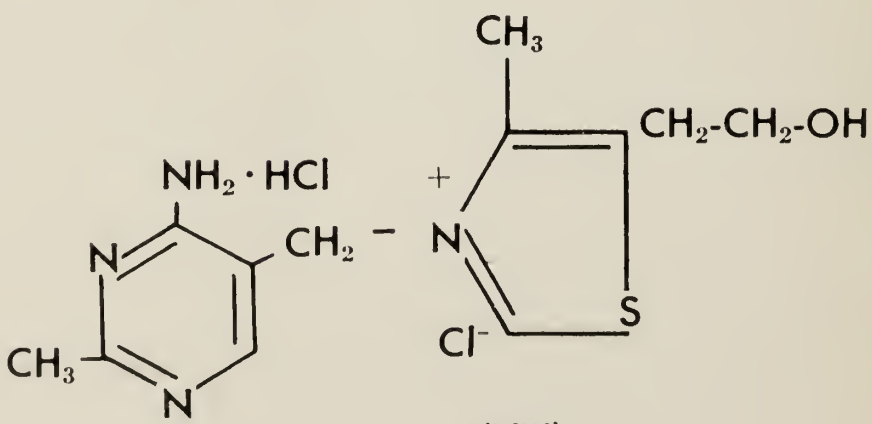
Polishing: The removal of inner bran layers.

Breakage of the kernels is a difficulty in rice milling, since the milled product is graded according to the content of head rice (unbroken kernels). This is a particularly serious problem with long grain rice, and any method of reducing the amount of breakage would be of value to the rice miller. As has been suggested in connection with wheat, a chemical is needed which would facilitate the removal of the bran.

During the milling of white rice, a proportion of the vitamins are removed along with the bran and germ, and several methods have been devised for retention of nutrients. Use of brown rice (hull removed but most of the bran and germ intact), or undermilling, is one approach. Parboiling the rice is another method; this consists of soaking the rough rice in hot water for several hours to diffuse the water-soluble vitamins from the hull and bran into the endosperm. After drying,



(VII)



(VIII)

the parboiled rice is milled by the same procedure as white rice. A third method is the fortification of white rice by enrobing about one-half of 1 per cent of the grains with niacin (VII), thiamine (VIII), and iron (I-33). The law requires that white rice for sale in Puerto Rico and South Carolina must be fortified.

Brown, undermilled, and parboiled rice are all susceptible in varying degrees to oxidative rancidity. The application of a suitable antioxidant might reduce deterioration in these products.

f. Corn

Some corn meal, still produced by grinding between millstones, contains the germ and retains a rich, oily flavor, but is highly susceptible to oxidation. The addition of an antioxidant should retard spoilage. Another problem in the production of corn meal is the loss of yellow color, and a solution may lie in the addition of carotene or artificial colors.

g. Barley

The principal food utilization of barley is in pot or pearl barley. A major problem is its attractiveness to insects. When stored near other grains, barley is consistently the first to be infested. Occasionally a batch of barley kernels will have a blue color, making it unsuitable for food use.

LITERATURE CITED

I-1. Maclay, W. D., and D. K. Mecham
1954. Problems and program on wheat utilization at the Western Utilization Research Branch. Trans. Amer. Assn. Cereal Chemists, **12**, 87.

I-2. United States Department of Agriculture, Bureau of Agricultural Economics
1953. Consumption of food in the United States 1909–1952. Agriculture Handbook No. 62 (Sept. Suppl. July 1958).

I-3. United States Department of Agriculture, Agriculture Research Service
1954. Losses in agriculture. Publication ARS-20-1, June (Mimeographed).

I-4. Milner, M., and W. F. Geddes
1954. Respiration and heating. In Storage of Cereal Grains and Their Products, ed. by J. A. Anderson & A. W. Alcock. Amer. Assn. Cereal Chemists, St. Paul, Minnesota.

I-5. Yen, Y., M. Milner, and H. T. Ward
1956. Treatment of wheat with ionizing radiation. II. Effect on respiration and other indices of storage deterioration. Food. Tech. **10**, 411.

I-6. Milner, M., and Y. Yen
1956. Treatment of wheat with ionizing radiation. III. The effect on breadmaking and related properties. Food Tech. **10**, 528.

I-7. Michelbacher, A. E.
1954. Insects attacking stored products. Advances in Food Res. 4, 312.

I-8. Haeussler, G. J.
1952. Insects. Yearbook of Agriculture, United States Department of Agriculture, p. 141.

I-9. Hart, E. B.
1952. Abuse of data on the biologic value of proteins. Nutrition Rev. **10**, 129.

I-10. Anon.
1956. Pfizer launches lysine additive, see 20 million pound potential. Food Field Reporter, 24 (26), 54.

I-11. Harper, A. E.
1956. Amino acid imbalances, toxicities and antagonisms. Nutrition Rev. **14**, 225.

I-12. Allison, J. B.
1956. Evaluation of dietary protein. Nutrition Rev. **14**, 129.

I-13. Anon.
1956. Nutrition board now considers amino acid addition attractive. Food Field Reporter, 24 (25), 22.

I-14. Scott, J. H.
1951. Flour milling processes. Chapman and Hall, Ltd. London.
I-15. Geddes, W. F.
1951. Technology of cereal grains. In The Chemistry and Technology of Food and Food Products, ed. by M. B. Jacobs. 2nd Ed., Vol. III, Interscience Publishers, Inc., New York.
I-16. Harrel, C. G., and B. M. Dirks
1955. Cereal and cereal products. In Handbook of Food and Agriculture, ed. by F. C. Blanck. Reinhold Publishing Corporation, New York.
I-17. Anon.
1955. Optical bleach for sugars and flours. Food Manuf. 30, 351.
I-18. MacAdams, L. P.
1955. Fungal enzymes in bread production. Food Manuf. 30, 274.
I-19. Anon.
1956. How engineering revolutionizes old art of breadmaking. Food Eng., 28, 74; Flour to fermented dough in two minutes. Food Eng., 28, 98.
I-20. Wiseblatt, Lazare.
1956. Bread flavor. Conference on chemistry of natural food flavors, National Academy of Sciences, National Research Council, Advisory Board of Quartermaster, Committee on Foods. Nov. 8–9, Chicago, Illinois.
I-21. Bechtel, W. G.
1955. A review of bread staling research. Trans. Amer. Assn. Cereal Chemists 13, 108.
I-22. Garnatz, G.
1954. What the baking industry needs to know about wheat and flour. Trans. Amer. Assn. Cereal Chemists, 12, 79.
I-23. Bechtel, W. G., D. F. Meisner, and W. B. Bradley
1953. The effect of the crust on the staling of bread. Cereal Chem., 30, 160.
I-24. Glabe, E. F.
1950. A discussion of the characteristics of sodium diacetate as a mold and rope inhibitor. Trans. Amer. Assn. Cereal Chemists, 8, 53.
I-25. Feig, M.
1950. Diarrhea, dysentery, food poisoning, and gastroenteritis. Amer. Jour. Public Health, 40, 1372.
I-26. Melnick, D., H. W. Vahlteich, and A. Hackett
1956. Sorbic acid as a fungistatic for foods. Effectiveness of sorbic acid in protecting cakes. Food Res. 21, 1, 133.
I-27. Brackman, R. A.
1954. Chemical leavening agents. Trans. Amer. Assn. Cereal Chemists 12, 43.
I-28. Pyler, E. J.
1952. Baking science technology. Vol. II. Siebel Publishing Co., Chicago, Illinois.
I-29. Logue, P.
1951. Leavening in prepared mixes. Trans. Amer. Assn. Cereal Chemists, 9, 119.
I-30. Joslin, R. P., and J. V. Ziemba
1955. New leavener triggered by heat. Food Eng. 27, 59.
I-31. Stuckey, B. N.
1955. Increasing shelf life of cereals with phenolic antioxidants. Food Tech. 9, 585.
I-32. LeClerc, J. L.
1933. Macaroni products. Cereal Chem., 10, 383.
I-33. Michus, R. R.
1955. Seals enriching additives on white rice. Food Eng., 27. 91.
I-34. Geddes, W. F.
1959. Recent developments in foods from cereals. Jour. Agr. Food Chem., 7, 605.
I-35. Harris, R. S.
1959. Supplementation of foods with vitamins. Jour. Agr. Food Chem. 7, 88.

Wine

1. Introduction

In terms of the sum of money spent annually for food in the United States, a small proportion, approximately 0.1 to 0.2 per cent of the food dollar, is spent on wines. The *per capita* consumption of wines in this country is shown in Figure J-1; the data for the graph were obtained from a wine periodical (J-1) and from the estimated population according to the U. S. Census Bureau. Only about 5 per cent of the wine consumed in the United States from 1950 through 1956 was imported; the rest was supplied by a domestic production which amounted to approximately 130 million gallons per year between 1954 and 1956, and which was centered in California and, to a lesser extent, in northern New York. As a point for comparison, the average yearly wine production during the same period in France and Italy was approximately 1.5 billion gallons per country.

The potential market for the use of chemicals in wine production in France and Italy is much lower than the above figures indicate, however, because most of these foreign wines are sent to market in bulk containers and sold directly from the barrels with so rapid a turnover that there is little or no concern for heat, cold, or color stability. In wines produced for export, however, chemicals to facilitate processing or to upgrade quality would be beneficial, and these countries do export in considerable quantities.

In brief, wine is produced in the following way: The grapes are stemmed and crushed, and in the production of white wines the juice is separated from the skins. Sulfur dioxide is added to retard the growth of undesirable organisms, and fermentation is initiated by the addition of a culture of yeast. For red or pink wines, the skins are removed from the fermenting "must" after sufficient color has been extracted. The fermentation is allowed to go to completion, or, in the case of fortified wine, is stopped by the addition of alcohol when the desired sugar content is reached.

The clarifying steps consist of a number of operations involving some or all of the following processes: settling, racking, cooling, heating, fining, and filtering to remove any material that might lead to the formation of sediment or turbidity. Aging in wood or in bottles depends upon the quality and type of wine desired. Much of the wine produced in California leaves the winery 2 months to 1½ years after the grapes are crushed.

More detailed information concerning the production of wines may be found in publications by Amerine and Joslyn (J-2), Cruess (J-3), and Joslyn and Amerine (J-4).

2. General problems

There are a number of points in wine production at which the use of chemicals might facilitate an operation or improve quality.

Deterioration can occur during the period of shipment from vineyard to winery. Growth of molds, "wild" yeast, and bacteria, in addition to physical breakdown with oxidation and metal pickup, are the major problems. Chemicals are needed to retard deterioration, but since most wine grapes are sent to local wineries, this problem is relatively limited.

The presence of molds, wild yeast, and bacteria on grapes, necessitates the use of an agent to retard their growth in grape

Fig. J-1. U.S. per capita consumption of wines.

"must" under the usual winery conditions. A suitable replacement for sulfur dioxide is one of the most serious problems which confronts the wine industry.

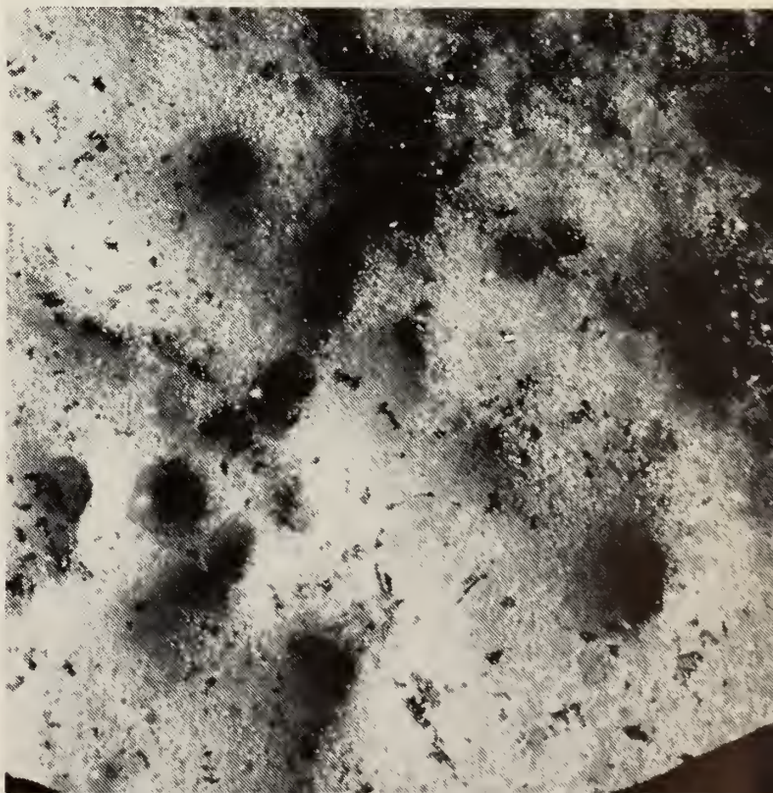
The principal objections to sulfur dioxide are the undesirable odor and taste it imparts, and the fact that it is responsible for the accumulation of acetaldehyde during fermentation, which may influence color stability in red wines. To illustrate the seriousness of this problem, the French Government has posted a prize, which has remained unclaimed, to stimulate the development of a satisfactory sulfur dioxide substitute in wine production. While it would be difficult to find another single chemical which possesses all the advantageous properties of sulfur dioxide, such as its selectivity in inhibiting the growth of undesirable bacteria and yeast, its property as an antioxidant, and its clarifying, dissolving, and acidifying influences, perhaps a suitable combination of chemicals could be found which would give the desired effects. For instance, Verona (J-5) suggested that selection of desirable yeast for fermentation be made on the basis of their differences in nutritional requirements, and perhaps addition of specific antimetabolites to natural "must" would inhibit the growth of undesirable species of yeast.

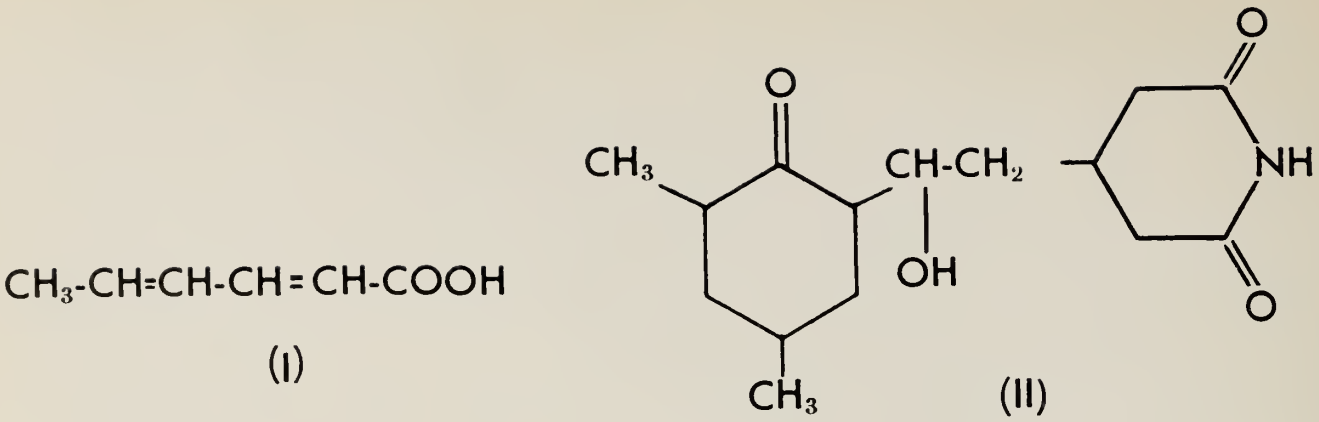
Approximately 35 per cent of the grapes crushed in California are fermented then distilled into brandy. The sulfur dioxide added during fermentation is quite corrosive to the distillation columns, and in addition, is responsible for the accumulation of residual acetaldehyde during distillation, which presents a removal problem. The question of the toxicity of a replacement for sulfur dioxide in distilling material is not critical, provided the substitute is nonvolatile or decomposes to nontoxic products upon heating.

Current methods for controlling fermentation are refrigeration, addition of alcohol or SO_2, and removal of yeast by filtration. A valuable agent in the production of standard quality, stable, sweet table wines would be one that could control the conversion of sugar by stopping or suppressing fermentation. At present, sulfur dioxide, bulk or bottle pasteurization, or combinations of these are used to stabilize sweet table wines. The possibility of the use of sorbic acid (I) in combination with sulfur dioxide is worthy of investigation. Sorbic acid is reported to inhibit yeast growth, while sulfur dioxide in much smaller quantity could control the growth of lactic acid organisms.

Antibiotics may be applied to control fermentation, and some work in this field has already been started in Europe. Actidione (II) is reported to stabilize wines in concentrations as low as 1 ppm. Actually, the presence of a natural antibiotic in grape "must" itself has been recognized recently. La Fourcade (J-6) reported the presence of an antibiotic (botryticin) in "must" from grapes on which the mold *Botrytis cinerea* was allowed to grow, and she showed that the addition of botryticin retards the rate of fermentation. The growth of this mold on grapes in certain areas of France, Ger-

White table wine fermentation in a closed cask. (Wine Institute photo.)





many, and Hungary increases the concentration of sugar by facilitating the loss of water. In addition, the mold metabolizes a sufficient quantity of acid to produce balanced high-quality, natural, sweet wines, among the most expensive in the world.

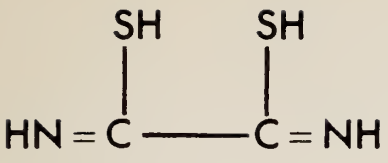
Extraneous "fermentations," and bacterial spoilage are widespread in the wine industry. Antibiotics, halogenated fatty acids such as chloracetic acid, and other chemicals have been applied to the problem, but none of these have been approved for use. The subject has been reviewed recently by Vaughn (J-9).

Copper or iron in wines, even in trace amounts of a few parts per million, not only cause the formation of sediment or turbidity, or both, but also cause deteriorative changes in flavor. However, the exclusive use of stainless steel and other inert materials in the winery is usually economically impractical. At present, the exposure to undesirable metals is kept at a minimum, and excessive amounts of metals either are removed by the use of "Cufex" [$K_2Fe_2(CN)_6$], or stabilized by the addition of citric acid in the case of ferric phosphate cloud. Joslyn and Lukton (J-7) have reported rubeanic acid (III) to be a very promising, relatively nontoxic agent for the removal of copper, and suggest further testing under winery conditions. E. D. T. A. (ethylenediamine tetracetic acid) (IV) does not bind copper or iron sufficiently to prevent cloud formation in some of the wines tested. Another approach might be the use of an ion-exchange process to remove excessive amounts of trace metals.

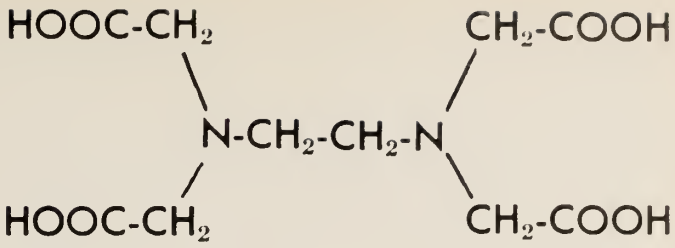
Although a number of fining agents are used to clarify wines, there is still need for improvement. These agents are utilized in wine production to coagulate and settle suspended materials. A disadvantage of the use of materials such as bentonite, a special clay, is the amount of wine that is lost due to the formation of a voluminous precipitate which is difficult to filter. Polyvinylpyrrolidone (V) has recently been added to the list of clarifying agents allowed by the Alcohol Tax and Tobacco Division of the Internal Revenue Service, but preliminary tests of this agent for clarifying wines have not given promising results.

Much of the tartrate in wines must be removed to prevent formation of undesirable sediments in the bottle when exposed to low temperatures. At present, these salts are separated by cooling the wine below 20°F. for one week to one month, followed by filtration. Perhaps the use of chemicals to remove or stabilize the tartrates would be economically feasible. Tartaric anhydride (VI), a complex material made by heating tartaric acid slightly above its melting point, is reported to prevent precipitation of tartrates in wines (J-8), and the use of ion-exchange resins to remove these salts is becoming common in Italy. Use of the latter in the production of wines in the United States might be worth investigating.

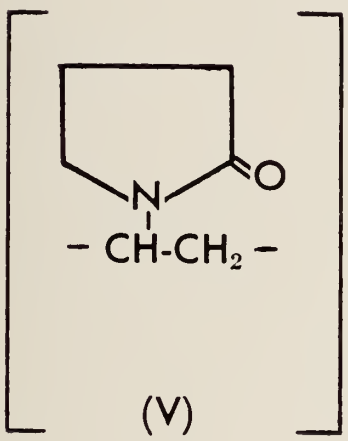
Heat may be used in any or all of the following steps: Color extraction from



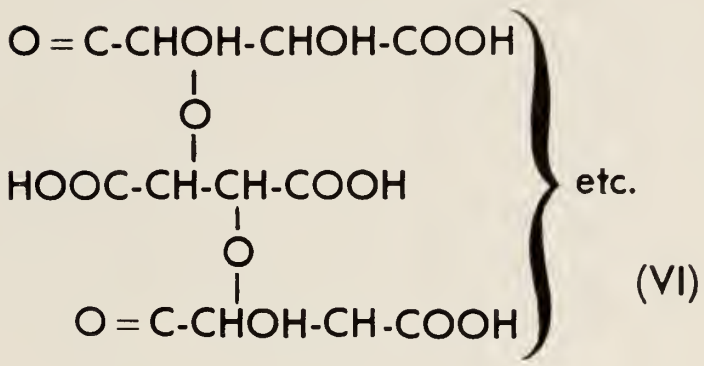
(III)



(IV)



(V)



(VI)

skins, precipitation of proteinaceous material to prevent turbidity, and inactivation of yeast at the time of bottling. Except in the production of some sherry wines, heating at any stage of production has a deleterious effect on the quality of the product. Thus, a method for avoiding these heating steps would be of value to the wine industry. A chemical should be found which would facilitate the extraction of color from the skins, or which would promote the transfer of flavoring constituents from grapes to wines. In the case of protein cloud in wine, the use of proteolytic enzymes might be of value in the clarification process.

Most sherry wines produced in California are baked at 120° to 140°F. for 2 to 4 months. It might be possible to catalyze the deve'opment of the characteristic sherry flavor, and thus reduce the heating time.

Oxygen scavengers should be useful in removing oxygen from wines at the time of bottling, and investigation of the practicability of adding an enzyme such as glucose oxidase might be of value. The use of a nitrogen atmosphere during processing and bottling should aid in reducing the amount of dissolved oxygen in wines.

Other winery problems include the breakdown of pigments in red wines, and the slight browning of white wines in the bottled products; the need for a catalyst to speed the maturation of rough young wines, lacking bouquet, into wines having a balanced bouquet of a fine aged wine: and the constant menace of vinegar flies around the wineries.

LITERATURE CITED

J-1. Anon.
1946, 1954, 1957. Wines and Vines. 27 (4) 1946; 32 (4) 1954; 38 (4) 1957.
J-2. Amerine, M. A., and M. A. Joslyn
1951. Table wines. University of California Press, Berkeley and Los Angeles.
J-3. Cruess, W. V.
1947. The principles and practice of wine making. The Avi Publishing Co., Incorporated, New York.
J-4. Joslyn, M. A., and M. A. Amerine
1941. Commercial production of dessert wines. California Agr. Exp. Sta. Bull. No. 651, Sept.
J-5. Verona, O.
1956. Recent microbiological advance in oenology. Food Res. 21, 402.
J-6. La Fourcade, Suzanne
1954. Contribution a L'étude des activeurs et des inhibiteurs de la fermentation alcoholique de moûts de raisin. Theses: A La Faculte des Sciences de Bordeaux.
J-7. Joslyn, M. A. and A. Lukton
1953. Prevention of copper and iron turbidities in wine. Hilgardia 22, 451.
J-8. Scazzola, M. F.
1956. Sur un produit inhibiteur de la cristallisation du tartre dans les vins. Ann. fals. et fraudes, 49, 159.
J-9. Vaughn, R. H.
1955. Bacterial spoilage of wines. Advances in Food Research 6, 67.

K

Beer

1. Introduction

The annual production of beer in the United States has remained at approximately 2.8 billion gallons since 1948. The *per capita* consumption of beer, shown in Figure K-1, indicates that it has not regained the popularity it had before prohibition. The changes in consumption of other beverages, included in Table K-1, also illustrate this trend.

Table K-1. U. S. *Per Capita* Consumption of Beverages (K-10) Consumption (gallons).

Commodity	1911-1914	1951-1956	Per cent change
Milk	32.14	36.05	12
Coffee	19.31	33.61	74
Beer	20.53	16.55	−19
Tea	15.60	10.40	−33
Soft drinks	0.83	10.27*	1270
Juices	0.03	3.21†	1070
Liquor	1.47	1.13	−23
Wines	0.59	0.89	51

* 1949 to 1952.
† 1950 to 1953.

The steps involved in the production of beer can be briefly described:

Malting. Malting involves the germination of barley, and its purpose is to obtain maximum enzyme development with minimum loss of food material. This point is reached when growth has developed to approximately three-quarters of the length of the grain, when it is stopped by drying.

Mashing. The malt is added to cooked cereal grains, and the action of the malt enzymes converts insoluble carbohydrates to sugars.

Boiling. When the proper amounts of fermentable and unfermentable sugars and dextrin have been produced, the action of the enzymes is stopped by heating the mash to boiling, which also destroys

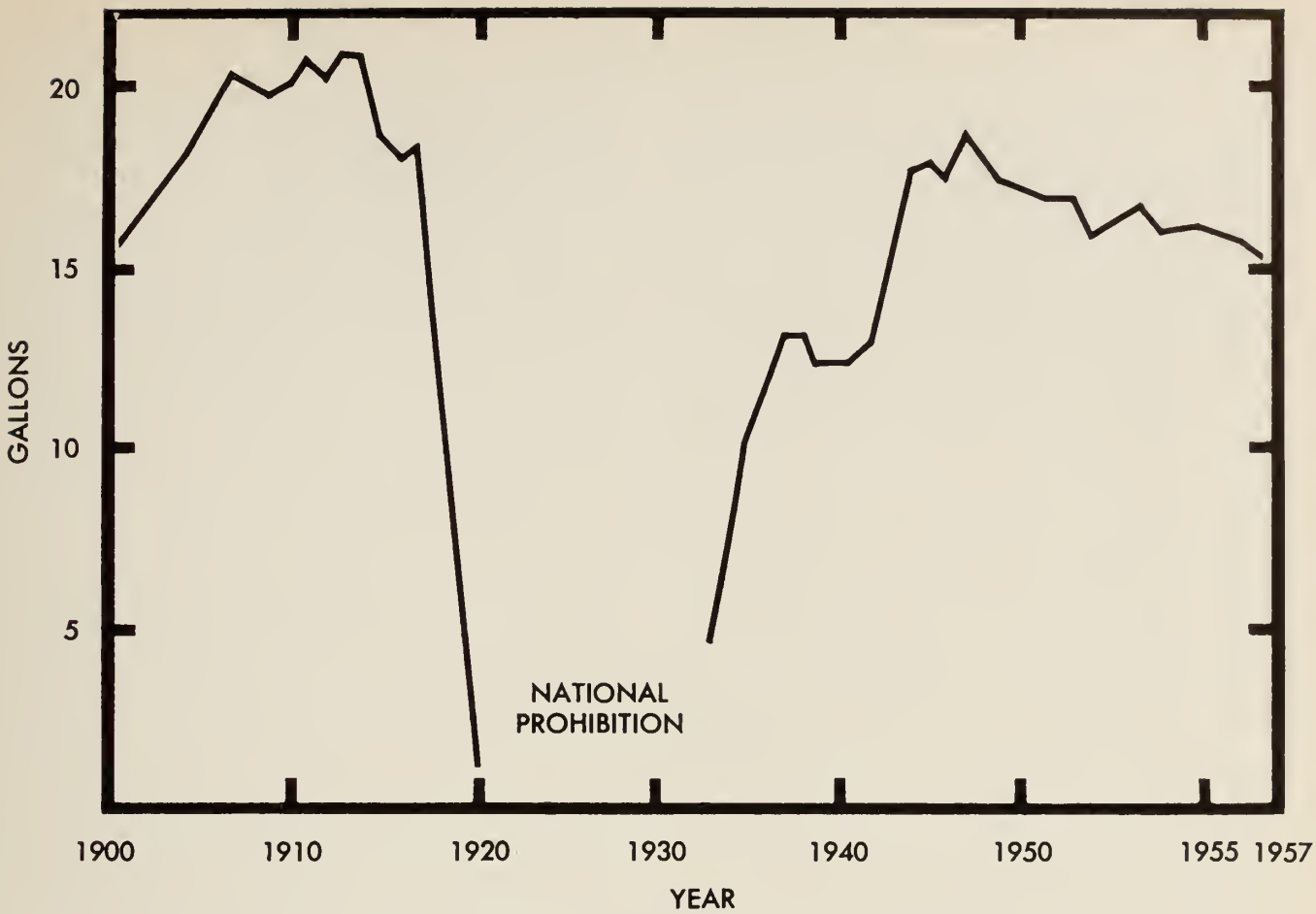


Fig. K-1. U.S. per capita consumption of beer.

any undesirable organisms. At this temperature, the flavor and preservative principle from hops are extracted, the more complex proteins are coagulated, and the mixture is concentrated.

Fermenting. The material is then cooled to 60°F., and a quantity of yeast starter is added to initiate fermentation.

Clarifying and carbonating. When fermentation is completed, the beer is stored and the yeast is allowed to settle out. Antioxidants, such as sulfites or ascorbic acid, are widely used at this point. Following preliminary storage, beer is finished by filtering, cooling, carbonating, and chill-proofing. In chill-proofing, a proteolytic enzyme is added which hydrolyzes protein sufficiently to prevent cloud formation at low temperatures.

2. General problems

The problems in the beer industry, haze formation, flavor changes, and "gushing" usually arise after packaging. During production, acid-forming bacteria may grow and give rise to the formation of lactic or acetic acid, but since the material is cooked before fermentation, the growth of these organisms does not create a serious problem when proper sanitary precautions are taken.

Beer is usually pasteurized after packaging to destroy the yeast and spoilage organisms which might cause deterioration of flavor and appearance. However, since pasteurization has a deleterious effect on the flavor and stability of beer (K-1), a number of researchers have investigated the possibility of substituting sterile filtration (K-2), ultraviolet irradiation (K-3), or chemical treatment (K-4). The use of hydrogen peroxide and similar compounds has been investigated, but none is used commerically in the U. S. The production of sterile beer by means other than pasteurization was one of the major topics of discussion at the 1947 European Brewery Convention Congress held in Lucerne, Switzerland. Kringstad (K-1) holds that an ideal an-

tiseptic would be one that would (1) destroy the microorganisms or render them incapable of growth within a short time, and (2) then decompose into a harmless substance without affecting the quality of the product.

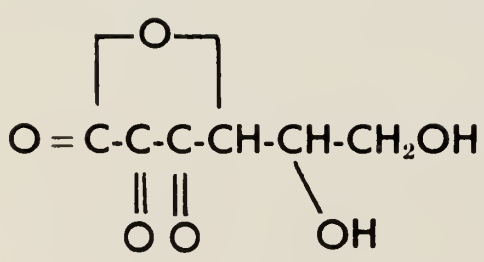
The idea of an antienzymatic compound suitable for use in beer production also is attractive. Such an agent could be added to stop all biochemical activity when optimum conditions have been attained.

Even though precautions are taken to reduce contact with air when beer containers are being filled, in most cases some oxygen is incorporated into the product, causing haze and flavor problems. To counteract the effect of oxygen, ascorbic acid may be used as an antioxidant. There is some question as to its appropriateness, since the oxidized ascorbic acid, dehydroascorbic acid (I), or its breakdown products, may act as an oxidizing agent (K-5). Another limitation is that ascorbic acid is incapable of removing all the oxygen, and even small quantities of oxygen are damaging. Attempts to lower the oxygen content by the use of the glucose oxidase enzymes have resulted in off-flavors. The oxidation is further complicated by the catalytic effects of iron or copper in amounts greater than 0.5 ppm. Currently, glucose oxidase is being evaluated as an oxygen scavenging agent in beer.

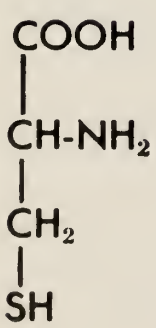
The mechanism of haze formation in beer is still unknown (K-6). Proteins, polyphenols, metals, and oxygen have been mentioned as factors involved in this kind of deterioration, but the presence of oxygen is the most important single factor. Oxidation-haze can result from either proteins or polyphenols. Protein oxidation is suggested to be the oxidation of sulfhydryl groups of the amino acid cysteine (II) in the protein, which causes the protein to become insoluble because of the disulfide cross linkages formed.

Chill-haze is the formation of a colloidal precipitate of protein or protein-tannin complex when beer is cooled. The problem can be eliminated by the use of proteolytic enzymes during processing; however, the foaming quality of the beer decreases with increasing protein hydrolysis. "Collupulin," a chill-proofing agent manufactured by the Wallerstein Laboratories, does not seem to present this difficulty.

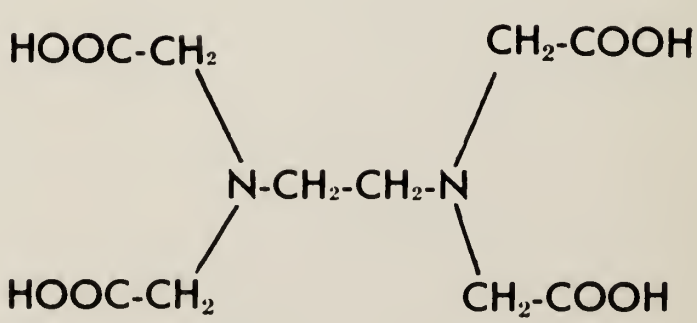
The sporadic occurrence of "gushing beer" ("wild beer") has been a problem of long-standing to the beer industry (K-7, K-8). Gushing is the rapid release of carbon dioxide when a beer container is first opened, and it is believed to be caused by the presence of minute particles in the liquid upon which the carbon



(I)



(II)



(III)

dioxide can be released. Traces of metal, products of oxidation, and prolonged low-temperature storage, contribute to the problem, and there is also some evidence that it may be protein-induced. It has been found that the addition of a small amount of ethylenediamine tetracetic acid (III) inhibits "gushing" caused by the more common metal contaminants (K-8); however, its use in commercial practice is not permitted. Gushing is also reported to be reduced or eliminated by the use of ascorbic acid (K-9).

The beer industry needs an effective method for removing or inactivating both oxygen and metals in beer, and a substitute for pasteurization. In developing chemicals to alleviate these problems, the instability of beer and its extreme sensitivity to off-flavor must be taken into consideration.

LITERATURE CITED

K-1. Kringstad, H.
1949. Production of sterile beer by means other than pasteurization. Prog. in Brew. Sci., 1, 171.
K-2. Oscood, G.
1949. Sterile filling. European Brewery Convention, 1st Congress, 1, 202.
K-3. Juillerat, A.
1949. Essai sur la stérilisation des bouteilles a biére au moyen de rayons ultraviolet. European Brewery Convention, 1st Congress, 1, 195.
K-4. Jacobsen, H. R., and J. Nestaas
1949. The use of hydrogen peroxide as a beer preservative. European Brewery Convention, 1st Congress, 1, 188.
K-5. Urion, E., L. Chapon, S. Chapon, and M. Metche
1956. Fixation of oxygen by beers treated with ascorbic acid. Reprinted in Amer. Brewer, 89, 56.
K-6. Barton-Wright, E. C.
1956. The problem of protein haze in bottled beer. Wallerstein Laborat. Comm. 19, 127.
K-7. Gray, P. P., and I. Stone
1949. Experiments on wild beer. Wallerstein Laborat. Comm. 12, 311.
K-8. Gray, P. P. and I. Stone
1956. Metal induces wildness in beer. Wallerstein Laborat. Comm. 19, 345.
K-9. Stone, I., and P. P. Gray
1956. Ascorbate as an antioxidant for beer. Wallerstein Laborat. Comm. 19, 287.
K-10. Stanford Research Institute
1958. Chemical economics handbook. Stanford Res. Inst. Menlo Park, California.

L

Coffee and Tea

1. Introduction

In the United States, coffee is more important than tea as a beverage, although on a world-wide basis, tea is second only to water. In 1956, the United States imported over 55 per cent of the coffee and about 9 per cent of the tea involved in world trade, amounting to 2.81 billion pounds and 100.52 million pounds, respectively. *Per capita* consumption records, as shown in Figure L-1, indicate an over-all increase in the use of coffee and a slight decline in that

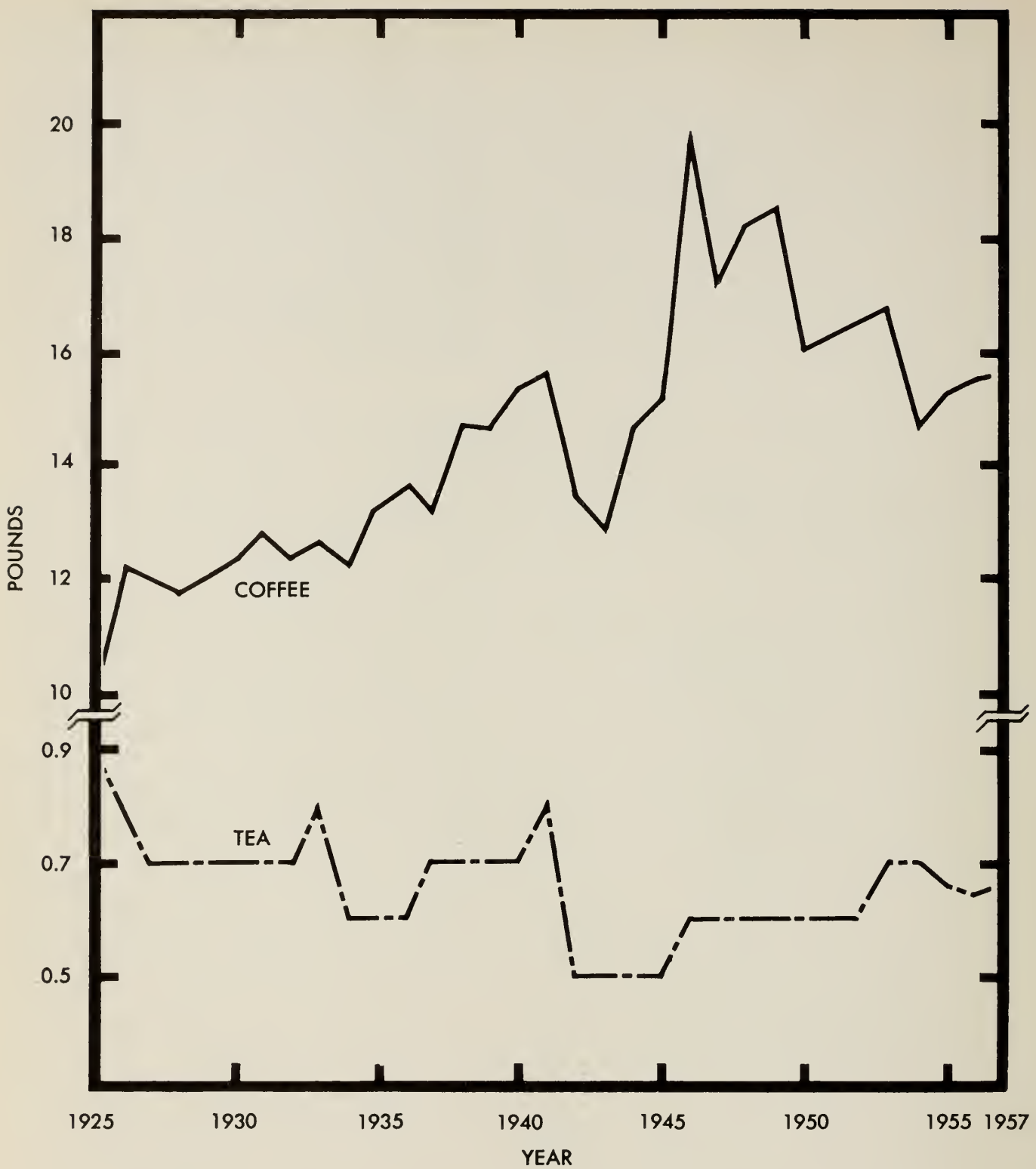


Fig. L-1. U.S. per capita consumption of coffee and tea.

of tea. This increase in our coffee consumption has been attributed to the proximity of the producing areas, absence of import duties, higher standard of living, and sustained purchasing power in the United States (L-1).

Most of our coffee comes from Brazil, and Ceylon provides a major part of the tea. Tables L-1 and L-2 indicate the sources and 1956 import levels of these important commodities.

Research on coffee is relatively limited, although the Coffee Brewing Institute annually publishes *A Survey of World Literature on Coffee* (L-2). More detailed information on the processing of coffee and tea also is available (L-3, L-4, L-5).

2. Commodity problems

a. Coffee

After harvest, the outer husks of the coffee berries are removed either by the "dry" or the "wet" process, both of which are referred to as curing. The dry method consists of thoroughly drying the berries by exposure to sunlight or heat, and then removing the hull by hand or a special machine. In the wet process, the berries are soaked in water and the hull partially removed by abrasion. The material is then allowed to ferment and disintegrate the remaining hull, which is removed by washing; finally the beans are dried. The resulting product is called "green coffee beans," and this is the coffee sold in world trade.

Before they are sold for consumption, green coffee beans are roasted under controlled conditions. This is a very important step in processing. The degree of roast is governed by the characteristics desired in the finished product, and therefore varies greatly in different parts of the world and even in different sections of the United States. A light roast is preferred in the west, the darkest in the south, and a medium in the east. Roasted coffee is then cooled, ground, and packaged, or used to make instant coffee.

Johnston (L-6) has reported that coffee quality can be significantly improved through the use of controlled procedures in wet curing, and the addition of pectic enzymes. The possibility of utilizing chemicals to facilitate the curing of coffee merits serious consideration.

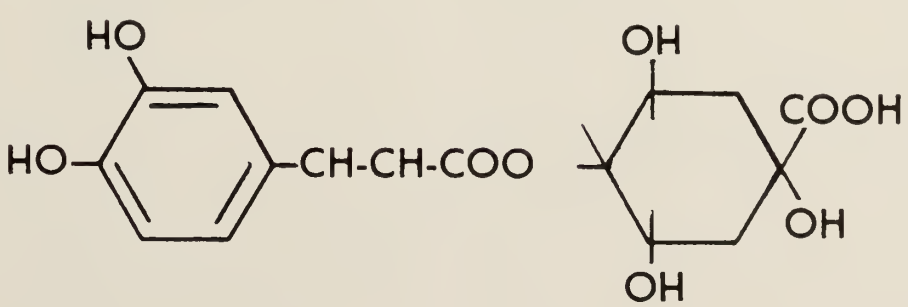
Table L-1. 1956 U. S. Coffee Imports (L-11).

Source	Million pounds
Brazil	1,307.7
Colombia	601.5
Mexico	137.4
Guatamala	107.6
El Salvador	79.7
Dominican Republic	50.6
All other countries	176.0

Table L-2. 1956 U. S. Tea Imports (L-11).

Source	Million pounds
Ceylon	41.90
India	31.67
Indonesia	12.14
Japan	3.54
Africa	4.70
All other countries	6.57

Improvements also might be effected by chemical treatment of the green coffee bean. Prescott (L-7) reports that the growth of a particular species of mold on the green beans improves flavor; the resultant product is referred to as "cultured coffee." A patent reported to improve markedly the flavor of the roasted coffee has been issued for ultraviolet irradiation of green coffee containing a high content of chlorogenic acid (I) (L-8). It would be worthwhile to study the possibility of improving coffee flavor



(I)

by treating the green beans with chemicals, as is done to a certain extent in processing cocoa.

Roasted coffee, especially the ground product, deteriorates rapidly upon exposure to air. Desirable characteristics are preserved by sealing the coffee in cans under vacuum or in an inert gas; once the can is open, the coffee deteriorates rapidly. Coffee used in resturants, and to some extent in homes, is sometimes packed in paper bags, and since these packages are not airtight, the coffee loses its aroma and rapidly becomes unpalatable. It would be highly desirable to find a means of stabilization which would prevent this flavor deterioration; a chemical additive might be the answer to this serious problem.

Once coffee is brewed, the taste and aroma are quickly lost. The Coffee Brewing Institute suggests that restaurants prepare only enough coffee for 1 hour, but this is seldom possible. There is a real need for some treatment which would maintain the delightful qualities of freshly brewed coffee over a longer period of time.

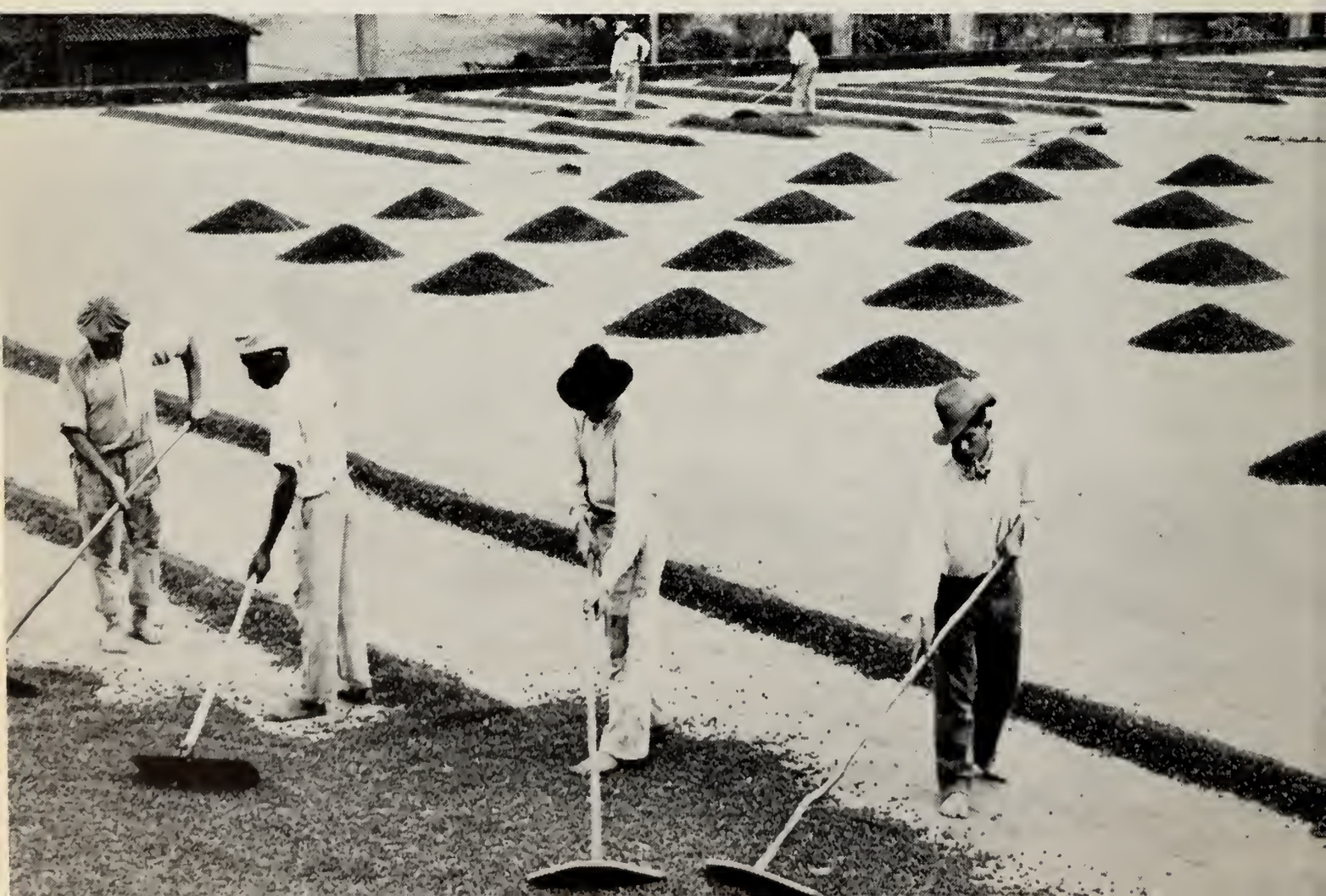
b. Soluble coffee

About 30 per cent of the coffee now sold in the United States is in soluble form. The success of soluble coffee is due primarily to its convenience; although its flavor is similar to that of ground coffee, the two are certainly not identical. The ultimate goal of producers is successfully to imitate the taste and aroma of freshly brewed coffee, and aromatics ordinarily lost in the manufacture of instant coffee may be collected and added back. However, this "add-back" results in stability problems. While many trade secrets are involved in the production of instant coffee (L-9, L-10), the flavor problem is common and the need for a flavor-holding and stabilizing factor is general.

c. Tea

Several steps are involved in tea processing. After picking, tea leaves are withered on racks at temperatures below

Coffee "cherries" spread out to dry on brick terraces. Only on the larger farms is this operation "mechanized" by using horses. (Safeway News photo.)



90°F. and then rolled to break the cells and free enzymes. Upon release of the enzymes, "fermentation" starts. The flavor, body, and color of black tea are determined during this step. The tea is then finished by "firing" (drying) to stop fermentation and to dry the tea leaves. In the preparation of green tea, only three operations are involved: Steaming to inactivate the enzymes in the leaves, rolling, and firing.

Tea processing operations in the United States are limited to cleaning, cutting, blending, and packaging. Brokers and distributors in this country believe that there are no major problems in the processing of tea which the use of chemicals might alleviate.

LITERATURE CITED

L-1. Wickizer, V. D.
1951. Coffee, tea and cocoa. Stanford University Press, Stanford, California.

L-2. Lockhart, E. E., and F. B. Bloomhardt
1953. A survey of world literature on coffee. Coffee Brewing Inst. Inc., New York. (annual)

L-3. Ukers, W. H.
1935. All about coffee. The Tea and Coffee Trade Jour. Co., New York, 2nd Ed.

L-4. Ukers, W. H.
1935. All about tea. The Tea and Coffee Trade Jour. Co., New York.

L-5. Ukers, W. H., and S. C. Prescott
1951. Coffee and tea. In the Chemistry and Technology of Food and Food Products, ed. by M. B. Jacobs, 2nd Ed., Vol. II. Interscience Publishers Inc., New York.

L-6. Johnston, W.R., and H. E. Foote
1951. Development of a new process for curing coffee. Food Tech. 5, 464.

L-7. Prescott, S. C.
n.d. Report of an investigation of coffee. Published by Joint Coffee Trade Publicity Committee, New York.

L-8. Proctor, B. E., and S. A. Goldblith
1951. Electromagnetic radiation fundamentals and their application in food technology. Advances in Food Res. 3, 119.

L-9. Winokur, W. C.
1953. What makes good soluble coffee. Food Eng., 25 (11) 76.

L-10. Kanninen, W. H., and E. S. Taub
1954. Manufacturing processes for soluble coffee. Coffee and Tea Ind. 77, (7), 11; (8), 19.

L-11. United States Department of Agriculture
1958. Agricultural Statistics 1957. Washington, D.C.

Cocoa and Chocolate

1. Introduction

The taste for chocolate has been well established on the American palate; next to vanilla, chocolate is the most popular flavor used in the United States. The importance of cocoa and chocolate in this country is indicated by our consumption of approximately 35 per cent of the world's production of cacao beans. The amounts of products made from cacao beans during 1947 and 1949 are shown in Table M-1.

In 1957, the U. S. imported 484 million pounds of cocoa (cacao) beans.

Fig. M-1. U.S. per capita consumption of cacao beans.

Table M-1. U. S. Output of Cocoa Preparations (in thousand metric tons).

Type of product	1947	1949
Chocolate coatings (total)	190.0	154.0
sweet	102.0	102.8
milk	73.0	33.7
liquor	15.9	17.5
Solid chocolate (except coating)	130.6	91.0
sweet	30.4	18.1
plain milk	61.7	39.6
nut milk	38.5	31.6
unspecified	....	1.7
Cocoa powders	78.4	69.6
consumer size	19.0	27.5
bulk container	45.8	34.0
sweetened or mixed	13.6	8.1
Cocoa butter	11.8	25.9
Chocolate syrups	43.1	not available

much of which, like coffee, came from Brazil. Table M-2 indicates principal sources of raw materials for the chocolate industry.

The trend in the U. S. *per capita* consumption of cocoa is shown in Figure M-1, indicating an over-all increase in the consumption of cocoa products during the last decade.

The terminology used for these products generally connotes one thing to the manufacturer and quite another to the consumer, which results in considerable confusion. Technically, the term *cacao* applies to the bean, either fresh, cured, or roasted; *cocoa* refers to the powder, used in preparation of the beverage; and *chocolate* refers to a manufactured product such as that used for confections.

In processing, cacao beans are cleaned and roasted. After roasting, the shells and germs are removed to give cocoa nibs, which are ground to chocolate "liquor," and the latter may be separated in a press giving cocoa butter and a residue which is pulverized to give cocoa powder. A number of alkaline materials are used in roasting, or added to the chocolate liquor, to impart a darker color and to improve flavor. In addition, this treatment produces a cocoa powder with improved suspension properties.

Breakfast cocoa, according to "Definitions and Standards under the Federal Food, Drug, and Cosmetic Act," is cocoa powder containing not less than 22 per cent cocoa fat. It may be spiced, flavored, or seasoned with certain optional ingredients.

Sweet chocolate, molded into different shapes, is made by mixing the chocolate liquor with some or all of the following ingredients: Cocoa butter, sugar, flavoring, milk solids, and emulsifying agents. Lecithin (I) and mono- and di-glycerides are usually added during processing to insure a smooth homogeneous product. The addition of 0.3 per cent lecithin reduces the viscosity of melted chocolate

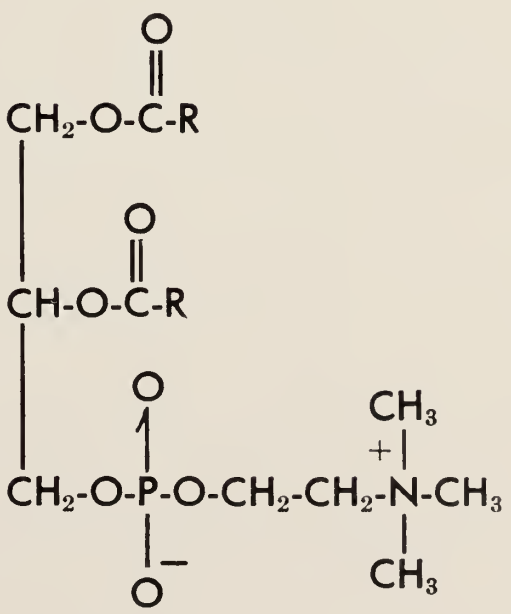
Table M-2. 1957 U. S. Cacao Imports (M-9).

Source	Million pounds
Brazil	110.26
Ghana	109.24
Nigeria	70.63
French West Africa	49.62
Dominican Republic	51.50
Ecuador	25.88
Venezuela	20.75
All other countries	46.23

sufficiently to decrease the amount of cocoa butter necessary by approximately 3 per cent. After mixing, the material is refined by being passed between steel rollers to reduce particle size, "conched" to improve flavor and texture, tempered to initiate proper crystallization, and molded into the desired shape. There are several publications which detail the operations in the production of cocoa and chocolate products (M-1, M-2, M-3).

2. General problems

The prime difficulties in the curing and storage of cacao beans center around the susceptibility of the beans to spoilage by microorganisms and insects, changes in the flavoring compounds and precursors. and variations in fermentation. However,



(I)

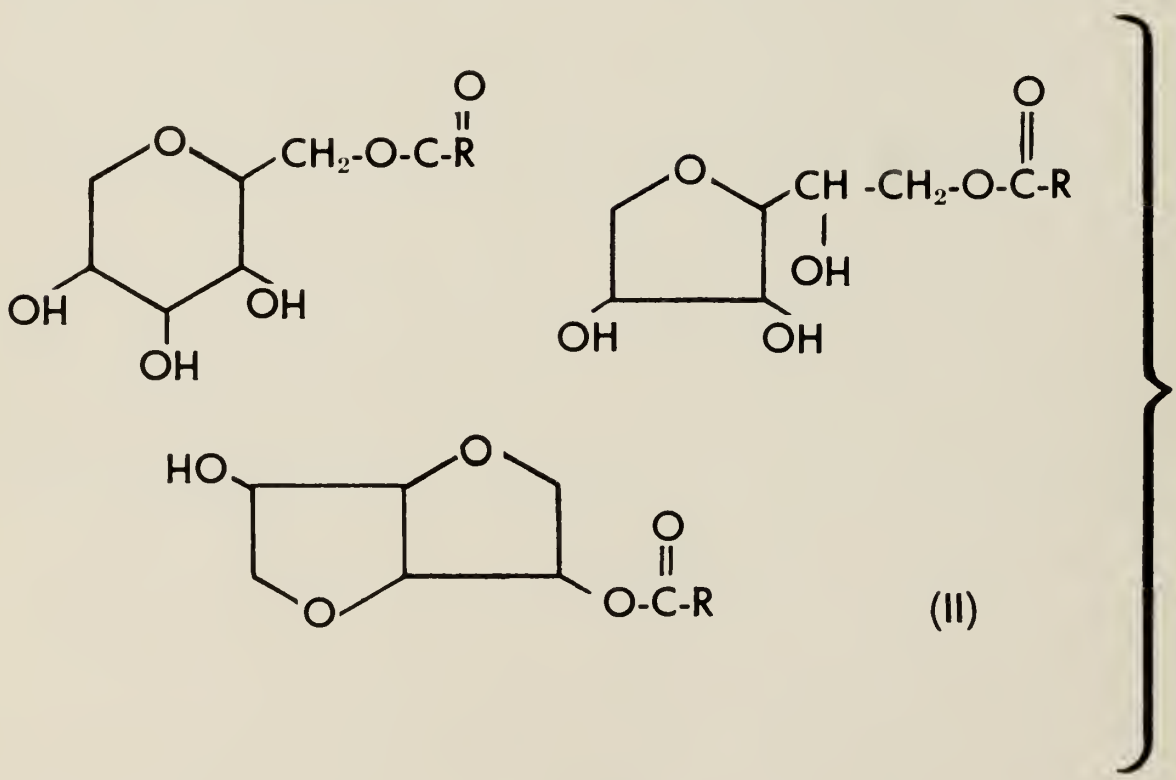
since these phases of manufacture are conducted almost exclusively outside the United States, they will not be pursued here. A recent review by Roelofsen (M-10) covers some of these problems in detail.

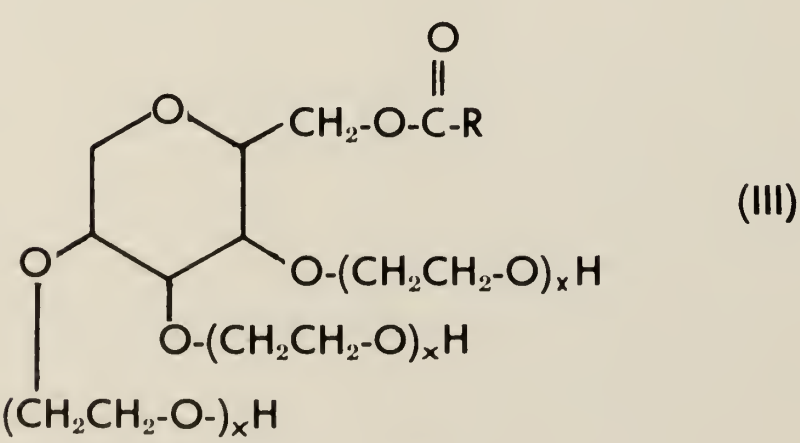
Obtaining quality raw materials is probably the industry's major problem, and one which frequently arises when imported raw materials are involved over which American processors have little or no control. As a first step, methyl bromide is used to fumigate cacao beans on arrival in the United States to eliminate insects, and the beans are sometimes fumigated again if infestation occurs pending processing.

A spoilage problem in chocolate-flavored milk is the growth of an organism whose spores are found in the cocoa powder. These spores originate on the surface of the cacao beans, and withstand roasting temperatures. They are now eliminated by dipping the cacao beans in dilute alkali; however, a fumigant might be found that would not only kill the insects, but also the heat-resistant spores.

In the chocolate-flavored milk, a thickening agent, such as carragheen, is used as a stabilizer, but there has been objection to its thick and rather slimy consistency. Better methods for stabilizing cocoa suspensions are needed for both chocolate milk and breakfast cocoa.

"Fat bloom" is still a problem in chocolate, and one easily apparent to consumers. This deterioration is due to fat separation when chocolate is exposed to warm temperatures; on cooling the fat resolidifies and produces a whitish appearance. Fat bloom may even occur on prolonged storage at moderate tempera-





tures. Actually, the deterioration is one of appearance only, and claims have been made that the addition of emulsifying agents now allowed under the Standards of Identity will retard it, as will proper tempering. Note that the addition of permitted emulsifiers and proper tempering only *delays* it; exposure to adverse conditions eventually will cause bloom to appear. A method for *preventing* this deterioration is needed.

Spans (II) and/or Tweens (III), synthetic emulsifying agents, are reported to delay fat bloom sufficiently to be of value (M-4, M-5). Neville has suggested that another approach to this problem is to modify cocoa fats by hydrogenation, fractionation, or isomerization.

"Stale milk" flavor which develops in chocolate within about one year, rancidity, and flavor loss, especially when chocolate is thin, are problems that occur in storage. The factors inherent in the development of desirable flavor, as well as of off-flavors, are still unknown, and investigation of chocolate flavor would be highly desirable. Such studies may disclose where the use of chemicals can enhance or retain flavor quality.

With the price of cocoa butter at about 60 cents per pound, a synthetic cocoa butter might be viewed with interest. Some work in this direction has been begun (M-6), and because of the high price of cacao beans and the appeal of chocolate flavored products, it seems inevitable that a substitute will be found (M-7).

LITERATURE CITED

M-1. Chatt, E. M.
1953. Cocoa: cultivation, processing, analysis. Interscience Publishing Co., New York.

M-2. Jensen, H. R.
1931. The chemistry, flavoring, and manufacture of chocolate confectionery and cocoa. Blakiston's Son and Co., Inc., Philadelphia, Pennsylvania.

M-3. Williams, C. T.
1953. Chocolate and confectionery. Leonard Hill, Ltd., London.

M-4. Easton, N. R.
1952. The use of modifiers in chocolate to retard fat bloom. Food Tech. 6, 21.

M-5. Neville, H. A., N. R. Easton and L. R. Bartron
1950. The problem of chocolate bloom. Food Tech. 4, 439.

M-6. Feuge, R. O.
1956. Edible fat replacement for cocoa butter in ration chocolate bars and coatings. Quartermaster Food and Container Inst., Final Report, July 1955–June 1956. Req. No. 49-106-041–56.

M-7. Alikonis, J. J.
1956. Cocoa and chocolate in today's foods. Cereal Sci. Today, 1, (2), 56.

M-8. United States Department of Commerce
1949. Census of manufacturers. Series MC61T-1, March.

M-9. United States Department of Agriculture
1958. Agricultural statistics 1957. Washington, D.C.

M-10. Roelofsen, P. A.
1958. Curing of cacao beans. Advances in Food Research, 8, 225.

N

Sugar and Honey

1. Introduction

The total consumption of cane and beet sugar in the United States during 1957 was approximately 9 million tons (97.1 pounds *per capita* at the retail weight) (N-1), and sugar and syrups provided 15.5 per cent of our energy and 33 per cent of the carbohydrate in our diet. The primary sources are sugar cane and sugar beets; other sugars in commerce are corn sugar, maple sugar, and lactose (milk sugar).

Of the cane sugar produced for use in the United States, more than one-half comes from Cuba. Hawaii, Republic of the Philippines, and Puerto Rico supply approximately equal amounts (about 12 per cent each), and 6 per cent is produced in the continental United States (mainly in Louisiana, Florida, and Texas). In these states, a total of more than 250,000 acres was harvested in 1956, with an average yield of 25.7 tons of cane per acre. Raw beet sugar produced in this country amounted to 2 million tons in the same year.

Sugar crystals, magnified approximately 23 diameters. (Great Western Sugar Co. photo.)

Sugar is isolated from cane and beets quite simply: either the cells are ruptured to release the sugar, or the sugar is leached from the cells. Extraneous material is removed (clarification), water is evaporated under vacuum, and the sugar is crystallized. In the case of cane sugar the process is separated into two operations; production of raw sugar and its refining.

The annual U. S. *per capita* consumption of honey during the last few years has been approximately 1.5 pounds. Honey processing is simple: the cap of the honeycomb is removed and the honey withdrawn by centrifugation (extracted honey), or alternately the comb is crushed and the extraneous material strained away (strained honey). After being heated to destroy yeast and remove air the honey is packaged.

2. General problems

a. Sugar

In clarification, an effective method for coagulating the suspended materials is necessary in order to facilitate the filtering of the sugar solution. Currently, lime and phosphoric acid are used in cane sugar refining. The use of the polyelectrolyte, Lytron X-886, a resinous polymer containing carboxyl groups, has been suggested for clarifying sugar cane juice (N-2); however, it does not appear to be compatible with the phosphoric acid. In purification of beet sugar, a larger quantity of lime is used along with carbon dioxide and sulfur. Thickening agents, such as algin, have recently come into use for purification (N-3), and ion-

exchange resins also have been used to some extent (N-3, N-4).

Prior to evaporation and crystallization, the sugar solution is passed through vegetable carbon or boneblack (char or animal charcoal) to remove color and inorganic materials. However, these agents are selective and lead to loss of sugar (which adheres to the surface), and are difficult to regenerate (N-5). It is conceivable that some chemical might be found which would facilitate this regeneration, or even bleach the color from the sugar solution and eliminate the use of char or charcoal altogether. Chlorine has been used for this purpose, but it does not function well in the production of all the desired products.

During the concentration of the sugar solution, scales form in the evaporator and necessitate shut-down and cleaning from time to time. A method is needed which would remove ions from solution prior to evaporation, or prevent the formation of scale.

It would also be highly desirable to develop an efficient method for controlling the rate of sugar crystallization. During this step, small amounts of inorganic material are occluded into the sugar crystals, and some way of preventing this or removing them from the crystals is needed.

Undesirable off-odors occasionally are found in sugar (N-6); "mustiness" and other odors have been mentioned. Although often off-odors are subtle, and detectible only to a keen nose, it still would be desirable either to remove them or to mask them.

More effective anticaking agents are another need of the sugar industry. Also occasionally, sugar is mentioned by food processors as a source of microbial contamination (N-7), because in the bulk shipment of granulated sugar in railway cars, moisture condenses on the walls of the boxcar, due to variations in outdoor temperature. A procedure which would eliminate this difficulty is needed.

A considerable amount of sugar is now being sold in liquid form because of the ease with which it can be handled. Although the sugar content is very high, there are yeasts which can grow in this material. Use of ultraviolet irradiation in the storage tanks prevents the growth of microorganisms on the surface, but is effective only to a depth of a few millimeters. Some agent is needed to prevent the growth of these annoying organisms.

b. Honey

Some of the problems involved in marketing honey are granulation, fermentation, discoloration, loss of flavor and aroma, and turbidity (from occluded air).

Although granulation does not spoil honey, it renders it inconvenient in use. Warming redissolves the sugar, but is inconvenient. In addition, granulation leads to a lower concentration of sugar in the liquid phase and allows the growth of tolerant yeasts. Honey production

One hundred-pound bags of refined sugar stacked in a warehouse. (Photo by Sugar Information, Inc.)

would be benefited by agents which would prevent the crystallization of sugar.

Fermentation by tolerant yeasts can be especially troublesome if, between beekeeper and processor, the moisture content rises above about 18 per cent. However, the processor heats the honey to facilitate handling and any yeasts that might cause later spoilage are usually destroyed at this time. Heating reduces the viscosity of honey sufficiently to allow escape of air bubbles which, if not removed, would cause a turbid product. Extended heating, however, affects flavor and color adversely. Heat treatment can be reduced by adding benzoic acid to control yeast growth, but this is not commonly done because it is felt that consumers resist the presence of a "chemical."

The color of honey may darken in the presence of iron due to reactions involved in phenolic compounds. If an effective chelating agent, suitable for food use could be found, an investigation should be made into its possible use in this product.

LITERATURE CITED

N-1. United States Department of Agriculture, Bureau of Agricultural Economics
1953. Consumption of food in the United States 1909–1952. Agriculture Handbook No. 62 (Sept. Suppl. Oct. 1955).

N-2. Bonneville, A. B.
1953. Clarification of sugar cane juice with poly-electrolytes. Sugar, **48**, 36, Nov.

N-3. Alston, P. W., and R. A. McGinnis
1952. Recent development in beet sugar factory technology. Sugar, **47**, 33, Jan.

N-4. Weaver, H. E.
1956. Future of ion exchange in sugar refining. Sugar, **51**, 26, July.

N-5. Deitz, V. R.
1954. Current problem in refining with bone char. Sugar, **49**, 44, Jan.

N-6. Owen, W. L.
1953. Microorganisms responsible for off-flavors in refined sugar. Sugar, **48**, 53, July.

N-7. Owen, W. L.
1955. Sources of microbial contamination in sugar. Sugar, **50**, 44, Aug.

Spices

1. Introduction

Spices, defined by the Food and Drug Administration as, "vegetable substances used to season food," play a very important role in food preparation and consumption (O-1). Approximately 50 are presently in use, the addition of the proper amounts and types of which enhances the palatability and/or appearance of foods and increases their acceptability. Furthermore, spices stimulate the secretion of gastric juices and act as antioxidants (O-2, O-3); to a limited extent, they may act as preservatives.

The exact definition of the term "spice" is difficult to formulate. Originally, it applied to the exotic seasonings imported from tropical countries, but more recently it has come to include almost any type of seasoning. Those condiments derived from the leaves of plants are classed as "herbs"; those from the

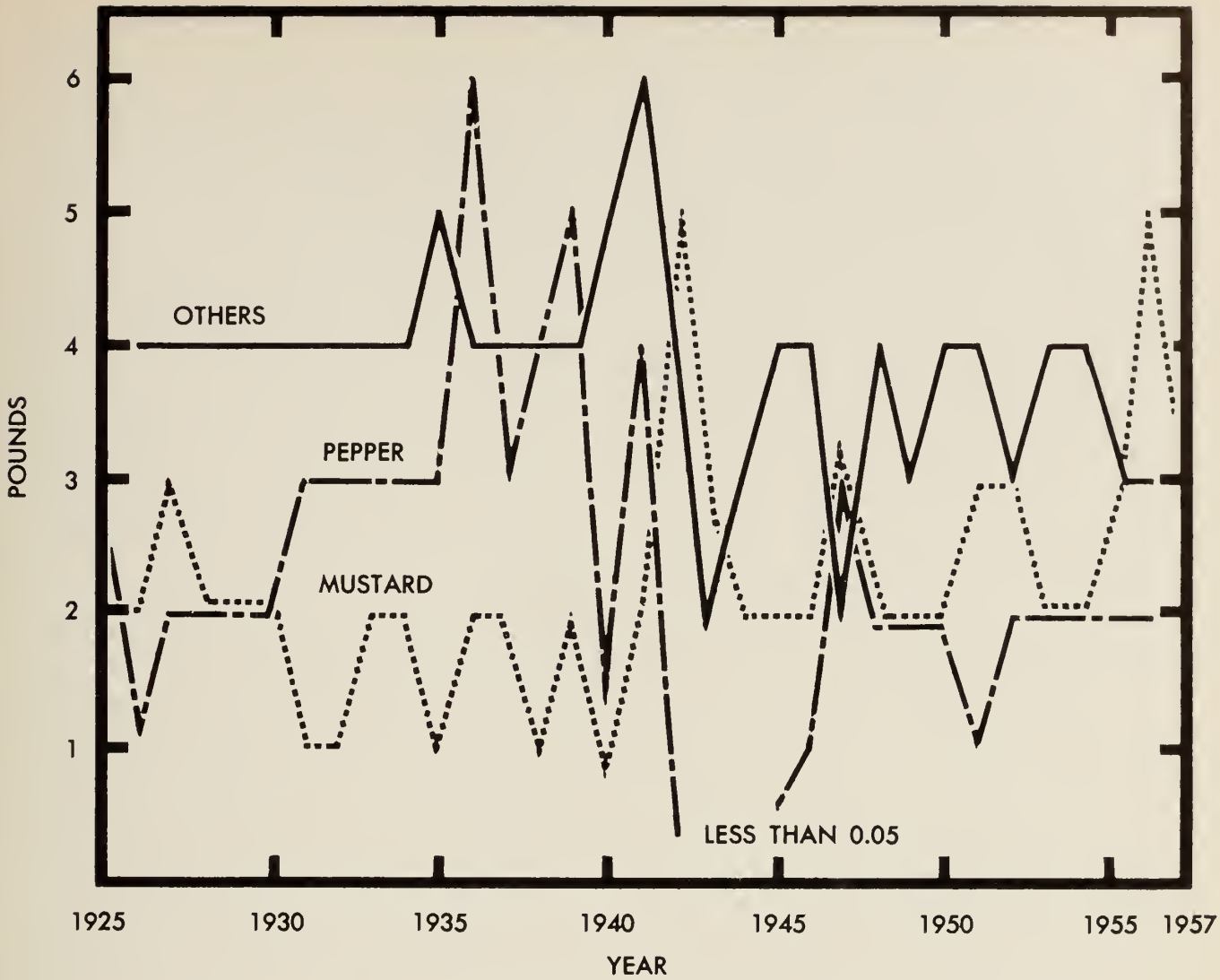


Fig. O-1. Apparent U.S. per capita consumption of spices.

Table O-1. Common Spices.

Spice	Plant	Portion	Origin
Allspice	Pimenta officinalis	Berry	Central America
Anise	Pimpinella anisum	Seed	India, South America
Caraway	Carum carvi	Seed	U. S., West Indies
Cardamon	Elettaria cardomum	Seed	India, Jamaica
Cinnamon	Cinnamomum species	Bark	Ceylon, Indochina
Cloves	Eugenia species	Bud	Zanzibar, Java
Ginger	Zingiber officinale	Rhizome	Ceylon, Zanzibar
Mace	Myristica fragrans	Aril	Molucca, West Indies
Mustard	Brassica species	Seed	Europe, U. S.
Nutmeg	Myristica fragrans	Nut	Molucca, West Indies
Paprika	Capsicum frutescens	Pod	Eastern tropics, Mexico
Pepper, black	Piper nigrum	Fruit	Eastern tropics
Pepper, red	Capsicum frutescens	Fruit	Eastern tropics, Mexico
Saffron	Crocus sativus	Stigma	Iran, Spain
Sesame	Sesamum indicum	Seed	India
Turmeric	Curcuma longa	Tuber	India

other plant parts as spices. Although about 100 different spices and herbs are sold, only the most common are listed in Table O-1.

In 1952, approximately 150 million dollars' worth of spices were sold in the United States. A considerable portion was sold directly to manufacturers of sausages, soups, tomato products, etc. U. S. *per capita* consumption of pepper, mustard seed, and other spices (O-4) is shown in Figure O-1.

Little research has been done on spices; the American Spice Trade Association sponsors some (O-5), and a limited amount is carried on by industry.

2. General problems

Food spoilage has sometimes been caused by organisms derived from spices. Ethylene oxide (O-6) has been used as a sterilizer, but while effective in killing vegetative cells, it has not been completely effective in killing spores. The spice industry needs a chemical more effective than ethylene oxide for sterilization purposes.

Color fading is a problem to the spice industry, particularly in the case of turmeric, red pepper, and paprika, and is crucial since certain spices are used to a large extent to add or improve color. Lease and Lease (O-7, O-8) reported that the addition of an antioxidant to paprika and cayenne pepper greatly reduced the loss of red color during storage. The development of an effective antioxidant could be of great value to spice producers.

Insects infest red pepper but not black pepper, and it would be extremely interesting to determine the reason for this preference. If black pepper should be found to contain a natural repellent, then the study of its chemical nature might lead to the rational development of an insecticide for red pepper and possibly for many other foods.

The flavoring constituents in whole spices are well protected; however, grinding reduces this protection in proportion to fineness. An economical method for retaining the flavor potency of ground spices would be of interest and value, since these products are used up slowly in the home, and the use of a stabilizing agent is warranted. A rather obvious suggestion is to enrobe ground spices with film on the assumption that the deterioration is due to the loss of volatile constituents.

In areas where the humidity is high, molding of ground black pepper is a problem. There are several additives which inhibit mold growth in foods, and

Attractive packaging is an aid in selling spices to consumers. (Safeway News photo.)

the practicability of adding these or other compounds to black pepper should be investigated.

Flavor interaction (between spices and foods) remains a relatively unexplored field. It is believed that chemical reactions occur between flavoring constituents and spices; in some cases the development of the full flavor, or an undesirable flavor, requires considerable time. The one fact known for a certainty is that a given food may be greatly enhanced by the addition of certain spices, and another food unpleasantly seasoned by these same spices. Flavor deterioration during food processing and storage perhaps also can be classed under flavor interaction, the chemical reactions which occur in food constituents during processing and storing, and which produce either a diminution of desirable flavor or off-flavors. An important phase of research in this area would be the chemical identification of the resulting flavoring substances as they are formed, the ultimate goal being to speed the reactions giving desirable flavors while retarding those giving off-flavors.

LITERATURE CITED

O-1. Worrell, L.
1951. Flavors, spices, condiments, and essential oils. Part I—Flavors, spices, condiments. In the Chemistry and Technology of Food and Food Products, ed. by M. B. Jacobs, 2nd Ed., Vol. III. Interscience Publisher, Inc., New York.

O-2. Chipault, J. R., G. R. Mizuno, J. M. Hawkins, and W. O. Lundberg
1952. The antioxidant properties of natural spices. Food Res. **17**, 46.

O-3. Chipault, J. R., G. R. Mizuno, and W. O. Lundberg
1955. Antioxidant properties of spices in oil-in-water emulsions. Food Res. **20**, 443.

O-4. United States Department of Agriculture, Bureau of Agricultural Economics
1953. Consumption of food in the United States 1909–1952. Agriculture Handbook No. 62 (Sept. Suppl. Oct. 1955).

O-5. Frank, J. J.
1953. Natural spices add much more than flavor. Food Eng., **25** (6), 78.

O-6. Pappas, H. J., and L. A. Hall
1952. The control of thermophilic bacteria. Food Tech. **6**, 456.

O-7. Lease, J. G. and E. J. Lease
1956. Effect of fat-soluble antioxidants on the stability of red color of pepper. Food Tech. **10**, 403.

O-8. Lease, J. G., and E. J. Lease
1956. Factors affecting the retention of red color in pepper. Food Tech. **10**, 368.

O-9. Hasselstrom, J., E. J. Hewitt, K. S. Konigsbacher, and J. J. Ritter
1957. Composition of volatile oil of black pepper. Jour. Agr. Food Chem., **5**, 53.

Animal Feed

1. Introduction

A survey of the possible use of chemicals to alleviate problems in, or to improve the nutritional quality of feed could be a major work in itself. Therefore, this section will deal only with the general problems which now face the industry.

The two-fold purpose in improving livestock and poultry production is to reduce the time required to achieve marketing weight, and to lower costs. In hopes of attaining these ends, approximately 3.5 billion dollars' worth of manufactured feed was bought in the United

States (P-1) in 1955. This was about 30 per cent of all feed consumed by the nation's livestock and poultry, exclusive of roughage and pasture, and it is likely that this percentage eventually will be doubled.

2. General problems

The general problems in the feed industry which might be attacked through the use of chemicals fall into four major groups: (1) Improvement of the availability of nutrients in feed; (2) removal of toxic material from feed; (3) protection of nutrients from storage and processing losses; and (4) addition of supplements to improve feed value or the health of livestock and poultry.

a. Nutrient availability

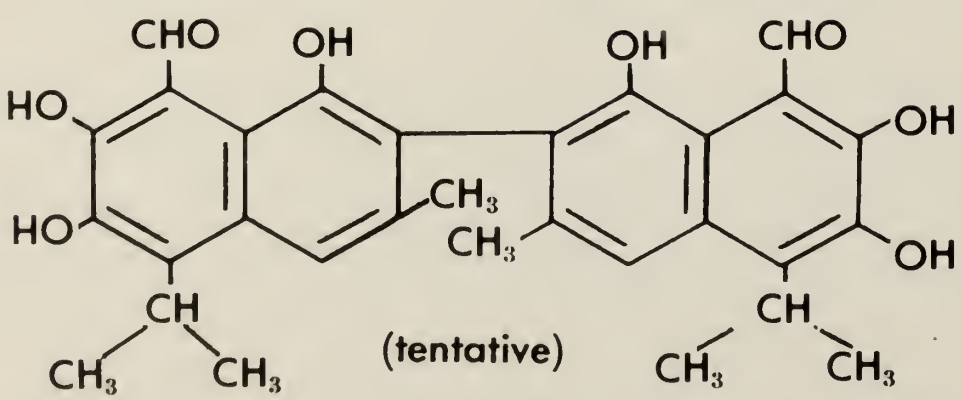
The addition of enzymes to improve the nutritional value of animal feeds is a rather controversial subject. It has been suggested for use in feeds to facilitate early weaning of young pigs, who have insufficient pepsin and pancreatic amylase to utilize feed efficiently (P-2). Some of the advantages of early weaning are saving on sow feed, more rapid rebreeding, and less chance of sow-to-pig disease. Further research is needed to clarify such use of enzymes, and further investigations should be conducted on the possible use of chemicals to improve the availability of nutrients in feed, not only for young animals, but also for livestock and poultry in general.

During the processing of the oil-bearing seeds whose residues are used as animal feed, heat may be applied to facilitate the removal of oil. Excessive heat treatment, however, can lead to decreased nutritional value. For example, it has been reported that a significant portion of the lysine in cottonseed meal is destroyed by autoclaving, which could account for the decreased nutritional value of heat-processed cottonseed meal (P-3). An agent might be developed which would either facilitate the removal of oils without heat treatment or prevent the destruction of lysine.

Still largely unstudied are the chemical components of the common feed materials which make essential nutrients unavailable by interfering with their absorption or utilization. Cottonseed meal contains a factor(s) which affects the availability of pyridoxine (P-13); a corn constituent binds niacin (P-14); common grains contain phytic acid which makes calcium unavailable (P-15); and a factor has been found in soybeans which interferes with methionine (P-16). Although there are processing methods which alleviate some of these problems, eventually some chemical means might be utilized which would make it possible to derive full benefit from the more costly feeds. This field has been reviewed by Lepkovsky (P-17).

b. Feed toxins

In addition to the feed stress factors mentioned in the preceding paragraph, several toxic compounds which occur in



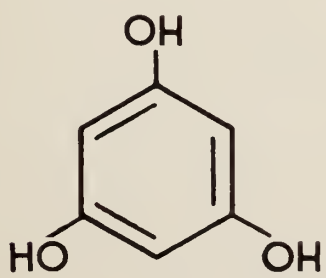
(I)

economically important feedstuffs and which have been studied in greater detail, might well be removed by chemicals.

For example, gossypol (I), a toxic material found in cottonseed meal, affects the growth of nonruminant animals. Aniline has been proposed for use to inactivate the free gossypol (P-5), but this treatment is not completely satisfactory for producing a feed for laying hens, since even in small quantities gossypol discolors eggs. Phloroglucinol (II) is very effective for inactivating free gossypol, but at its present cost its use is impractical (P-6). A number of other natural feedstuffs, such as linseed and alfalfa meal, also contain significant amounts of harmful materials. The development of economical chemicals to inactivate the toxic factors in feedstuffs would be of great value to this industry.

c. Nutrient protection

Antioxidants are added to animal feed to reduce the loss of fat-soluble vitamins, such as Vitamins A, D, and E, and to stabilize any unsaturated lipids which are added to, or occur naturally in feed. It has been estimated that, in 1956, approximately 2 million pounds of antioxidants were used in chicken feed alone (P-4), and at present, BHA and BHT (see Fats and Oils section) are used in livestock feed. The field of antioxidants is a highly competitive one: the Monsanto Chemical Company has developed 6-ethoxyl-1 2-dinhydro-2,2,4-trimethylquinoline (III), trademarked "Santoquin,"which is undergoing toxicological tests; Universal Oil Products has been testing some of the higher N,N'-dialkylphenylenediamines; the Crown-Zellerbach Paper Corporation has been exploring the properties of norconidendrin (IV); and the Oregon Forest Products Laboratory has studied dihydroquercetin (V) from Douglas Fir bark. It has been predicted that within the next decade the use of antioxidants may increase 100 per cent or more.



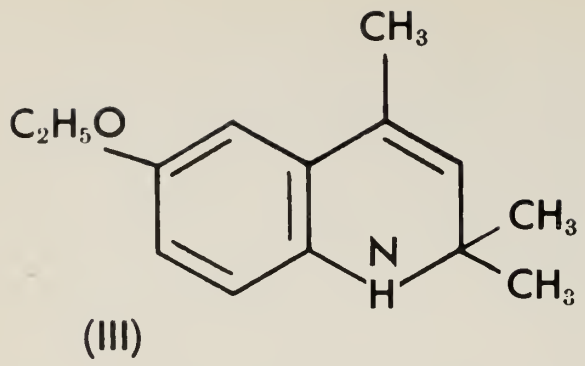
(II)

d. Feed supplements

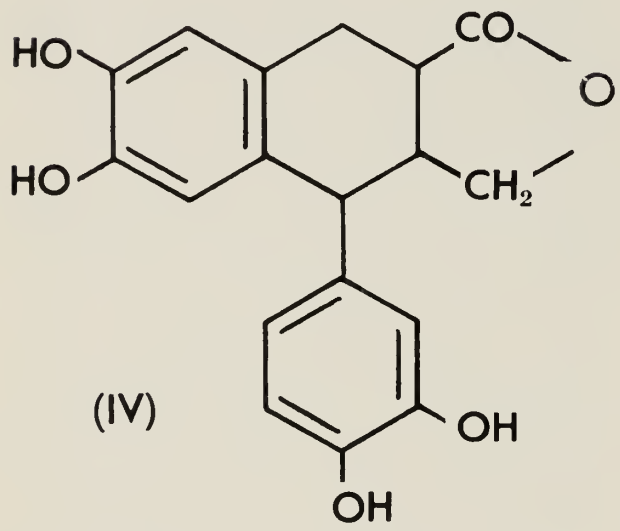
An extensive business has developed from the modern supplementation of feed to improve its nutritional value and the health of livestock and poultry. In 1955, approximately 80,000 tons of urea were added to feed (P-3) to help ruminant animals meet their protein requirement, and other protein substitutes such as propionaminde, ammonium salts of organic acids, and various ammoniated crude carbohydrates (ammoniated beet pulp, ammoniated citrus pulp) are currently under investigation for this purpose.

In addition large quantities of the amino acids methionine and glycine are being added to chicken feed (P-8). Actually, the addition of amino acids is a subject for controversy from both the economic and nutritional standpoint. A ton of fishmeal, for example, contains approximately 38 pounds of methionine and costs about $130, whereas 38 pounds of methionine alone costs $95. Thus, it is difficult to justify the use of synthetic amino acids in animal feed at their present cost, unless their value can be shown conclusively. The addition of lysine to animal feed is even less warranted than methionine because of its current high price.

A variety of pharmaceutical chemicals are now used as feed additives (P-9, P-10). The antibiotics, originally developed for human medicine, now find their principal use as feed additives (P-11). The antibiotic most widely employed for this purpose is penicillin; however, tetracyclines (Aureomycin and Terramycin), bacitracin, and hygromycin, are also used in quantity. The sales of these prod-



(III)

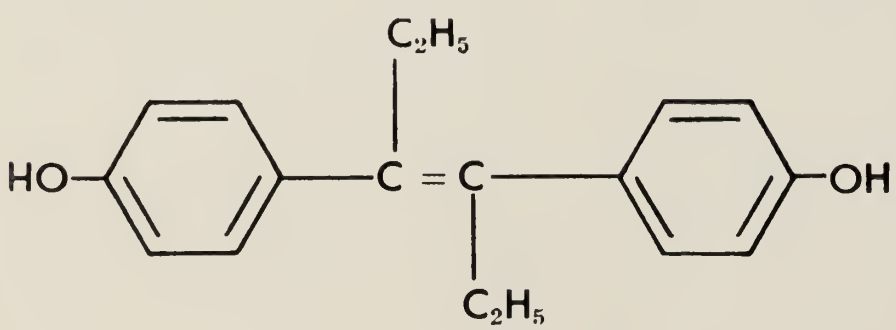


(IV)

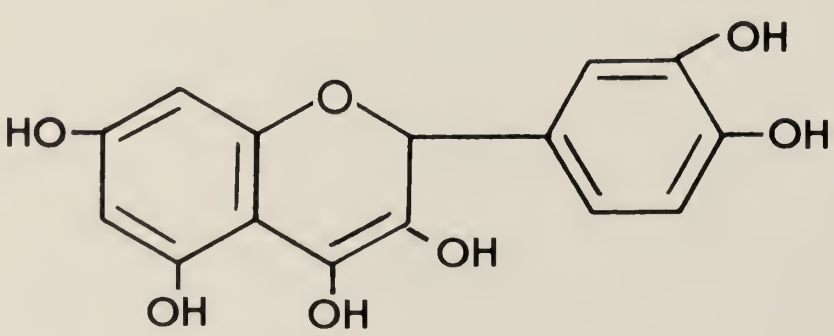
ucts for feed use amounted to about 26 million dollars' worth in 1954, and by 1955 reached 700,000 pounds, worth more than 46 million dollars.

Feed manufacturers also make extensive use of vitamins as additives. The most important of these, from a commercial viewpoint, are riboflavin, niacin, calcium pantothenate, choline chloride, and Vitamins A, D, E, and B_{12}. Hormones, too, have found increasing application in feeds during the last few years (P-12). Production of diethyl stilbestrol (VI), hexestrol, dienestrol, and other synthetic hormones for use in cattle, swine, sheep, and poultry feeds, has become a major business, and natural steroid hormones such as progesterone and estradiol have been approved by the FDA for use in lambs.

The use of medicated feed to combat internal parasites of animals has grown to major proportions (P-18). The most destructive of these parasites are internal nematodes, liver flukes, grubs, and lungworms in cattle; nematodes in sheep and goats; and kidney worms and roundworms in swine. Coccidia are a problem in cattle, sheep, and, particularly, in poultry. All together, these diseases cost the American farmer more than 500 million dollars annually. Table P-1 lists the most widely applied chemical medicants used at present by the feed industry;



(VI)



(V)

Table P-1. Principal Medicants Used in Animal Feeds.

Chemical name	Trade name or common name	Principal use	Used in
5-Nitro-2-furfuraldehyde semicarbazone	Nitrofurazone (NFZ)	Coccidiosis	Poultry
3,3′-Dinitrodiphenyl disulfide	Nitrophenide	Coccidiosis	Poultry
4,4′-Dinitrodiphenyl urea complexes	Nicarbazin	Coccidiosis	Poultry
2-Sulfanilamidoquinoxaline	Sulfaquinoxaline	Coccidiosis	Poultry
4,6-Dimethyl-2-sulfanilamido-pyrimidine	Sulfamethazine	Coccidiosis	Poultry
3-Nitro-4-hydroxyphenylarsonic acid	Arsonic acid	Coccidiosis	Poultry
4-Aminophenylarsonic acid	Arsanilic acid (Pro-gen)	Growth stimulant	Poultry, swine
Phenothiazine	.....	Nematocide	Sheep, cattle
Piperazine (and salts)	.....	Antihelminthic	Swine, poultry, horses
Cadmium anthranilate	.....	Antihelminthic	Swine
Sodium propionate	.....	Ketosis	Cattle

however, a great deal of research is being conducted on the subject, and it is to be expected that new, more efficient chemicals for use in veterinary medicine will be available in the near future.

Other medicinal agents, too, are finding use in animal feeds. Perhaps the most important of these are the tranquilizers, now being tested for their efficacy in increasing growth and feed-efficiency in cattle (P-19). Although experimental results are not generally available, the fact that many firms are actively studying the subject is an indication that there is a promising field for such compounds in animal production.

LITERATURE CITED

P-1. Brinegar, T.
1956. Feed manufacture and formulation. Cereal Sci. Today, 1, 62.
P-2. Anon.
1957. Enzymes in pig feed. Jour. Agr. Food Chem., 5, 484.
P-3. Conkerton, E. J., W. H. Martinez, G. E. Mann, and V. L. Frampton
1957. Lysine and arginine destroyed by autoclaving. Jour. Agr. Food Chem., 5, 560.
P-4. Anon.
1956. Food and feed antioxidants. Jour. Agr. Food Chem., 4, 667.
P-5. Rice, J. V.
1952. Use of aniline and other amines to inactivate gossypol. Buckeye Cotton Oil Co., U. S. Patent 2,607,687. Aug. 19.
P-6. Grau, C. R., T. L. Lau, and C. L. Woronick
1955. Inactivation of gossypol by treatment with phloroglucinol. Jour. Agr. Food Chem., 3, 864.
P-7. Anon.
1955. Urea outlook. Jour. Agr. Food Chem., 3, 816.

P-8. Anon.
1955. Synthetic amino acids. Jour. Agr. Food Chem., 3, 646.
P-9. Couch, J. R.
1956. Micronutrient problems in feed formulation. Cereal Sci. Today, 1, 191.
P-10. Moskey, H. E.
1953. Drugs in animal feed. Food, Drug, Cosmetic Law Jour., 8, 108.
P-11. Anon.
1956. Farmer's antibiotics. Jour. Agr. Food Chem., 4, 196.
P-12. Anon.
1955. Hormone feeding of livestock. Jour. Agr. Food Chem., 3, 819.
P-13. Kratzer, F. H., and D. E. Williams
1948. The relation of pyridoxine to the growth of chicks. Jour. Nutrition, 36, 297.
P-14. Laguna, J. and K. J. Carpenter
1951. Raw vs. processed corn in niacin-deficient diets. Jour. Nutrition, 45, 21.
P-15. McCance, R. A. and E. M. Widdowson
1942. Mineral metabolism of healthy adults. Jour. Physiol., 101, 44.
P-16. Hayward, J. W., H. Steenbock, and G. Bobsted
1936. The effect of heat as used in the extraction of soybean oil upon the nutritive value of the protein of soybean oil meal. Jour. Nutrition 11, 219.
P-17. Lepkovsky, S.
1953. Nutritional stress factors and food processing. Advances in Food Research 4, 105.
P-18. Anon.
1957. Chemicals vs. internal parasites. Jour. Agr. Food Chem., 5, 321.
P-19. Anon.
1957. Will tranquilizers find use in cattle feed? Chem. Week, 81 (9), 44.
P-20. Greenberg, J., D. J. Taylor, H. W. Bond, and J. F. Sherman
1959. Toxicity of amino-extracted soybean meal. Jour. Agr. Food Chem., 7, 573.
P-21. Todd, W. R.
1959. Mineral supplementation of foods and feeds. Jour. Agr. Food Chem., 7, 166.
P-22. Anon.
1958. Nitrofurans. Jour. Agr. Food Chem., 6, 877.

PART III—CHEMICALS USED BY THE FOOD INDUSTRY

In recent years, two surveys have been conducted to determine the chemicals in active use by the food industry: (1) a project at the Stanford Research Institute sponsored by the U. S. Army Quartermaster Corps (SRI Report S-101; September 1, 1947, and August 30, 1948), and (2) an investigation by the Food Protection Committee of the Food and Nutrition Board, National Research Council (see "The Use of Chemical Additives in Food Processing," Publication 398; February, 1956).

The first of these studies resulted in a noncritical list of all materials which had been found to have application in foods or food processing, and included many substances and mixtures of questionable use and origin. Although authentic examples of use were not generally provided, the report was important as the first such compilation ever attempted. The government survey attempted to list all those materials whose use was permitted by a regulatory agency, whether they were actually employed in practice or not. In addition, examples of the type and level of use were included.

On the following pages are listed those substances which are now actually used by the food industry, so far as it was possible to determine such application. In general, chemicals listed here are single compounds of known structure and composition. However, where the volume of use is great, certain important natural products which are mixtures (i.e., gelatin), or whose chemical structures are indeterminate (i.e., agar-agar) have been included. The chemical names used are those which are most common in food fields. In cases where the "common" name might conceivably be ambiguous, a "standard" name has also been given. The common names of the aliphatic acids are used, including valeric (C_5), caproic (C_6), enanthic (C_7), caprylic (C_8), pelargonic (C_9), and capric (C_{10}) acids and their derivatives.

The chemicals are listed principally by function (i.e., preservatives). Each of these sections is subdivided into commodity problems (i.e., microbial spoilage) under which application to specific commodity groups is indicated. Where the examples of use are not obvious, typical applications are shown in parentheses. Due to the wide range of levels at which food chemicals are added, no attempt has been made to indicate here the quantities of each substance involved.

CHEMICALS USED IN FOODS

PRESERVATIVES

Chemical	Example of Use
Microbial Spoilage	
c. Poultry	
Chlortetracycline (Aureomycin)	Uncooked poultry
Oxtetracycline (Terramycin)	Uncooked poultry
d. Fish and fish products	
Sodium benzoate	Salted codfish
Sorbic acid	Cured fish
Chlortetra cycline (Aureomycin)	Fresh fish and certain shellfish
e. Dairy products	
Calcium propionate	Sliced and cut varieties of cheese
8-Hydroxyquinoline sulfate	Cottage cheese
Sodium propionate	Sliced and cut varieties of cheese
Sorbic acid	Sliced and cut varieties of cheese
f. Eggs	
Sodium orthophenylphenate	Shell eggs
Sodium pentachlorophenate	Shell eggs
g. Fats and oils	
Benzoic acid	Margarine
Sodium benzoate	Margarine
h. Fruits and vegetables	
Ammonium chloride	Fresh fruits (generation of NH_3)
Benzoic acid	Jams, jellies, preserves
Biphenyl	Citrus fruits (wrappers)
Borax	Citrus fruits (wash water)
Calcium hypochlorite	Fruits and vegetables (wash water)
Chloroform	Dried fruits
Citric acid	Cauliflower for canning (blanch to retain color); frozen fruits
Ethyl acetate	Dried fruits
Ethylene dibromide	Dried fruits
Ethylene dichloride	Fresh strawberries
Ethylene oxide	Dried fruits
Isopropyl alcohol	Dried fruits
Melamine	Celery (wash water)
Methyl formate	Dried fruits
Methylene chloride	Dried fruits
Ozone	Fresh fruits and vegetables
Propylene oxide	Dried fruits
Sodium dimethy dithiocarbamate	Melons
Sodium hypochlorite	Fruits and vegetables (wash water)
Sodium orthophenylphenate	Fresh peaches and citrus fruits
Sorbic acid	Fresh fruit salad; orange and grapefruit sections
Sulfur dioxide	Fresh grapes
Tetraiodoethylene	Melons
Trichloroethylene	Fresh strawberries
Zinc dimethy dithiocarbamate	Melons
i. Cereal and cereal products	
Calcium propionate	Bread, rolls, and cake
Sodium diacetate	Bread, rolls, and cake
Sodium propionate	Bread, rolls, and cake
Sorbic acid	Cakes

Chemical	Example of Use
j. Wines	
Potassium bisulfite	(Retard growth of undesirable organisms)
Sodium bisulfite	(Retard growth of undesirable organisms)
Sulfur dioxide	(Retard growth of undesirable organisms)
k. Beer	
Polymixin B	(Yeast culture for beer)
n. Sugar and honey	
Benzoic acid	Honey
o. Spices	
Ethylene oxide	

Chemical deterioration

b. Meat	
Ascorbic acid	(Antioxidant)
Butylated hydroxyanisole (BHA)	Dry Sausage (antioxidant)
Citric acid	Dry Sausage (antioxidant)
Niacin	Hamburger (maintain color)
Sodium ascorbate	(Antioxidant)
c. Poultry	
Propyl gallate	Chicken soup base (antioxidant)
d. Fish and fish products	
Acetic acid	Canned shellfish (retard discoloration)
Aluminum salts	Canned crab (retard discoloration)
Ascorbic acid	Frozen fish (antioxidant)
Citric acid	Frozen fish; canned shellfish (antioxidant)
Tartaric acid	Canned shellfish (retard discoloration)
Sodium metaphosphate	Canned flaked fish (retard struvite formation)
Zinc salts	Canned crab (retard discoloration)
e. Dairy products	
Ascorbic acid	Milk (antioxidant)
Nordihydroguaiaretic acid	Cream, ice cream, and milk (antioxidant)
f. Eggs	
Ammonium hydroxide	Egg solids (stabilizer)
Catalase	Egg solids (glucose removal)
Citric acid	Egg solids (stabilizer)
Glucose oxidase	Egg solids (glucose removal)
Hydrochloric acid	Egg solids (stabilizer)
Hydrogen peroxide	Egg solids (glucose removal)
Lactic acid	Egg solids (stabilizer)
Phosphoric acid	Egg solids (stabilizer)
Sodium carbonate	Egg solids (stabilizer)
Tartaric acid	Egg solids (stabilizer)
g. Fats and oils	
Butylated hydroxyanisole (BHA)	(Antioxidant)
Butylated hydroxytoluene (BHT)	(Antioxidant)
Citric acid	(Antioxidant; metal scavenger)
Dilauryl thiodipropionate	(Antioxidant)
Distearyl thiodipropionate	(Antioxidant)
Gum guaiac	(Antioxidant)
Lecithin	(Antioxidant)
Monoisopropyl citrate	(Antioxidant; metal scavenger)
Nordihydroguaiaretic acid	(Antioxidant)
Phosphoric acid	(Antioxidant; metal scavenger)
Propyl gallate	(Antioxidant)
Sorbitol	(Metal scavenger)
Stearyl citrate	(Antioxidant; metal scavenger)
Thiodipropionic acid	(Antioxidant)
Tocopherols (Vitamin E)	(Antioxidant)

Chemical	Example of Use
h. Fruits and vegetables	
Ascorbic acid	Frozen fruits, canned mushrooms (antioxidant)
Citric acid	Cauliflower (blanch to retain color); frozen fruits (antioxidant)
Potassium bisulfite	Peeled fruits and potatoes (prevent browning)
Potassium metabisulfite	Peeled fruits and potatoes (prevent browning)
Sodium bisulfite	Peeled fruits and potatoes (prevent browning)
Sodium metabisulfite	Peeled fruits and potatoes (prevent browning)
Sodium sulfite	Peeled fruits and potatoes (prevent browning)
Sodium thiosulfate	Peeled fruits and potatoes (prevent browning)
Sulfur dioxide	Fruits (prevent browning)
i. Cereal and cereal products	
Butylated hydroxyanisole (BHA)	Prepared breakfast cereal and crackers (antioxidant)
Butylated hydroxytoluene (BHT)	Prepared breakfast cereal and crackers (antioxidant)
j. Wines	
Potassium bisulfite	(Antioxidant)
Sodium bisulfite	(Antioxidant)
Sulfur dioxide	(Antioxidant)
k. Beer	
Ascorbic acid	(Antioxidant)
Potassium bisulfite	(Antioxidant)
Sodium bisulfite	(Antioxidant)
Sodium sulfite	(Antioxidant)
Insecticides	
h. Fruits and vegetables	
Methyl bromide	Dried fruits
i. Cereal and cereal products	
Carbon disulfide	Grain
Carbon tetrachloride	Grain
1,1-Dichloro-1-nitroethane	Grain
Chloropicrin	Grain
Ethylene dibromide	Grain
Ethylene disulfide	Grain
Hydrogen cyanide	Grain
beta-Methylallyl chloride	Grain
Methyl bromide	Grain and flour (fumigation)
Piperonyl butoxide	Grain
Petroleum oil	Grain
Pyrethrum	Grain
l. Coffee and tea	
Methyl bromide	Coffee beans (fumigation)
m. Cocoa and chocolate	
Methyl bromide	Cacao beans (fumigation)

NUTRITIONAL SUPPLEMENTS

Vitamins	
e. Dairy products	
Niacin	Milk
Riboflavin (Vitamin B_2)	Instant chocolate milk
Thiamine (Vitamin B_1)	Milk and instant chocolate drink
Vitamin A	Milk and bleached cheese
Vitamin D	Evaporated milk, milk chocolate drink

Chemical	Example of Use
g. Fats and oils	
Carotene	Margarine, shortening, and skim milk (Vitamin A)
Vitamin A	Margarine and shortening
Vitamin D	Margarine and shortening
h. Fruits and vegetables	
Ascorbic Acid	Fruit juice
i. Cereal and cereal products	
Niacin	Enriched flour, bread, corn meal, macaroni products, farina, breakfast cereal, rice
Riboflavin (Vitamin B_2)	Enriched flour, bread, corn meal, etc.
Thiamine (Vitamin B_1)	Enriched flour, bread, corn meal, etc.
Vitamin D	Enriched flour, bread, farina, breakfast cereal
Amino acids	
i. Cereal and cereal products	
L-Lysine monohydrochloride	Bread, cookies, breakfast cereal
Minerals	
e. Dairy products	
Potassium iodide	Skim milk (iodine)
Ferric phosphate	Skim milk (iron)
Ferric pyrophosphate	Skim milk
Ferric sodium pyrophosphate	Skim milk
Ferrous sulfate	Skim milk
i. Cereal and cereal products	
Calcium carbonate	Enriched flour, bread, corn meal, etc. (calcium)
Calcium oxide	Enriched flour, bread, corn meal, etc. (calcium)
Calcium phosphate, monobasic	Enriched flour, bread, corn meal, etc. (calcium)
Calcium phosphate, dibasic	Enriched flour, bread, corn meal, etc. (calcium)
Calcium phosphate, tribasic	Enriched flour, bread, corn meal, etc. (calcium)
Calcium sulfate	Enriched flour, bread, corn meal, etc. (iron)
Ferric phosphate	Enriched flour, bread, corn meal, etc. (iron)
Ferric pyrophosphate	Enriched flour, bread, corn meal, etc. (iron)
Ferric sodium pyrophosphate	Enriched flour, bread, corn meal, etc. (iron)
Ferrous sulfate	Enriched flour, bread, corn meal, etc. (iron)

COLORING AGENTS

Natural coloring matter	
b. Meat	
Alkanet	Rendered fat and animal casings
Annatto	Rendered fat and animal casings
Carotene	Rendered fat and animal casings
Cochineal	Rendered fat and animal casings
Chlorophyll	Rendered fat and animal casings
Saffron	Rendered fat and animal casings
Turmeric	Rendered fat and animal casings
e. Dairy products	
Annatto	Cheese, buttermilk
Carotene	Skim milk, buttermilk, cheese
f. Fats and oil	
Annatto	Butter, lard, margarine
Carotene	Butter, lard, margarine

Chemical	Example of Use
Synthetic food colors	
FD&C Blue #1 and #2	
FD&C Green #1, #2, and #3	
FD&C Red #1, #2, #3, and #4	
FD&C Yellow #1*, #2*, #3*, #4*, #5, and #6	
b. Meat	
Certified food dyes	Animal and artificial casing
Methyl violet	Branding ink
d. Fish and fish products	
FD&C Orange #1	Kippered salmon
e. Dairy products	
Artificial green or blue color	Cheese (neutralize yellow color in curd)
FD&C Yellow #3*	Cheese
FD&CYellow#4*	Cheese
f. Eggs	
FD&C Al and Ca Lakes	Shell eggs
g. Fats and oils	
FD&C Yellow #3*	Butter, popcorn oil
FD&C Yellow #4*	Butter
h. Fruits and vegetables	
FD&C Blue #1	Canned peas, mint jellies, mint pears, cinnamon pears, maraschino cherries, cherry pie mix
FD&C Red #2	Canned peas, mint jellies, mint pears, cinnamon pears, maraschino cherries, cherry pie mix
FD&C Red #3	Canned peas, mint jellies, mint pears, cinnamon pears, maraschino cherries, cherry pie mix
FD&C Yellow #5	Canned peas, mint jellies, mint pears, cinnamon pears, maraschino cherries, cherry pie mix
i. Cereal and cereal products	
FD&C Red #2	Breakfast cereal
FD&C Yellow #3*	Yellow cake mix
FD&C Yellow #5	Breakfast cereal
Derived color	
b. Meat	
Hydrogen peroxide	Tripe (as a bleach)
Potassium nitrate	Cured meat
Potassium nitrite	Cured meat
Sodium nitrate	Cured meat
Sodium nitrite	Cured meat
e. Dairy products	
Benzoyl peroxide	Cheese (bleach)
g. Fats and oils	
Activated charcoal	Vegetable oils (bleach)
Activated earths	Vegetable oils (bleach)
Fuller's earth	Vegetable oils (bleach)
i. Cereal and cereal products	
Benzoyl peroxide	Flour (bleach)
Chlorine	Flour (bleach)
Chlorine dioxide	Flour (bleach)
Nitrosyl chloride	Flour (bleach)
Nitrogen oxides	Flour (bleach)
n. Sugar and honey	
Bonechar (char)	Sugar (decolorizer)
Lime (and CO_2)	Beet sugar (decolorizer)

* A proceeding is under way which would result in a ban of these coaltar colors from use in foods.

Chemical	Example of Use

FLAVORING AGENTS

Artificial flavors*

Acetaldehyde	(Black walnut flavor)
Acetanisol (methoxyacetophenone)	(Nutty flavor)
Acetic acid	(Rum flavor)
Acetoin (acetylmethylcarbinol)	(Butter flavor)
Acetophenone	(Cherry flavor)
Acetyl propionyl (pentandione)	(Butter flavor)
Acetyl valeryl (heptandione)	(Strawberry flavor)
Allyl caproate	(Pineapple flavor) (II)
Allyl caprylate	(Pineapple flavor)
Allyl cinnamate	(Pineapple flavor)
Allyl cyclohexyl propionate	(Pineapple flavor)
Allyl enanthate (allyl heptanoate)	(Pineapple flavor)
Allyl hexanoate	(Pineapple flavor)
Allyl pelargonate	(Pineapple flavor)
Allyl isothiocyanate	(Mustard flavor)
Allyl tiglate	(Pineapple flavor)
Allyl isovalerate	(Apple flavor)
Ammonium valerate	(Imitation black walnut flavor)
Amyl acetate	(Banana flavor, fruit flavors) (I)
Amyl alcohol	(Whiskey flavor)
Amyl butyrate	(Banana flavor, fruit flavors) (I)
Amyl caproate	(Pineapple flavor, apple flavor) (III)
a-Amyl cinnamaldehyde	(Fruity flavor)
Amyl cinnamaldehyde	(Strawberry flavor)
Amyl enanthate	(Coconut flavor)
Amyl formate	(Raspberry flavor)
Amyl isovalerate	(Peach flavor, fruit flavor) (II)
Amyl propionate	(Apple flavor)
Anethole	(Root beer flavor, anise flavor) (I)
Anisaldehyde	(Cherry flavor, vanilla flavor) (II)
Benzalacetone	(Fruity flavor)
Benzaldehyde	(Cherry flavor, almond flavor) (I)
Benzyl acetate	(Strawberry flavor, fruit flavor) (III)
Benzyl alcohol	(Fruity flavor)
Benzyl benzoate	(Raspberry flavor)
Benzyl butyrate	(Fruity flavor)
Benzyl formate	(Fruity flavor)
Benzyl isobutyrate	(Fruity flavor)
Benzyl propionate	(Fruity flavor)
Benzyl valerate	(Strawberry flavor)
Borneol	(Spice flavor)
Bornyl acetate	(Pineapple flavor)
Butyl acetate	(Raspberry flavor, fruit flavor) (III)
n-Butyl alcohol	(Whiskey flavor)
Butyl butyrate	(Fruit flavor) (III)
Butyl propionate	(Fruit flavor)

* Agents used in synthetic food flavors. The Roman numeral after some agents indicates the number of food items in which they are used. See H. L. Janovsky, Food Technol. **9**, 500 (1955).

Group (I) —15 items
Group (II) —12 items
Group (III)—14 items
Group (IV) — 5 items
Unnumbered—less than 5 items

Chemical	Example of Use
Butyraldehyde	(Nut flavor)
Butyric acid	(Butter flavor)
Capraldehyde (decanal)	(Citrus flavor) (III)
Caproic acid (hexanoic acid)	(Cheese flavor)
Caprylaldehyde (octanal)	(Citrus flavor) (IV)
Carvacrol	(General flavor)
Carvone	(Caraway, dill flavor) (II)
Cinnamaldehyde	(Cinnamon flavor, cola flavor) (I)
Cinnamyl acetate	(Fruity flavor)
Cinnamyl alcohol	(Fruity flavor)
Cinnamyl butyrate	(Fruity flavor)
Cinnamyl formate	(Fruity flavor)
Cinnamyl propionate	(Fruity flavor)
Cinnamyl valerate	(Fruity flavor)
Cinnamyl anthranilate	(Grape flavor)
Cinnamyl isobutyrate	(Pineapple flavor)
Citral	(Lemon flavor) (I)
Citronellal	(Fruity flavor) (III)
Citronellol	(Rose flavor)
Cuminaldehyde (p-isopropylbenzaldehyde)	(Mint flavor)
Cyclohexyl acetate	(Orange flavor)
Cyclohexyl butyrate	(Pineapple flavor, fruit flavor) (IV)
Cyclohexyl cinnamate	(Cherry flavor)
Decanal dimethylacetal	(Citrus flavor)
Decyl alcohol (decanol) (Alcohol C-10)	(Citrus flavor)
Diacetyl	(Butter flavor) (II)
Diallyl sulfide	(Garlic flavor)
Dihydrocoumarin	(Caramel flavor)
Dimethyl anthranilate (methyl N-methylanthranilate)	(Grape flavor)
Dodecalactone	(Fruity flavor)
Ethone (p-methoxyphenyl-pentenone)	(Vanilla flavor)
Ethyl acetate	(Pineapple flavor) (I)
Ethyl acetoacetate	(Apple flavor)
Ethyl benzoate	(Imitation cherry flavor)
Ethyl butyrate	(Strawberry flavor, fruit flavor) (I)
Ethyl caprylate	(Cognac flavor)
Ethyl cinnamate	(Fruit flavor)
Ethyl enanthate	(Grape flavor, pineapple flavor, coconut flavor) (II)
Ethyl formate	(Rum flavor, strawberry flavor) (III)
Ethyl furylacrolein	(Cinnamon flavor)
Ethyl isobutyrate	(Fruit flavor)
Ethyl isovalerate	(Fruit flavor)
Ethyl lactate	(Grape flavor) (III)
Ethyl laurate	(Spice flavor, fruit flavor)
Ethyl malonate	(Strawberry flavor)
Ethyl methylphenylglycidate (Aldehyde C-16)	(Strawberry flavor) (II)
Ethyl methyl p-tolylglycidate	(Strawberry flavor)
Ethyl nitrite	(Strawberry flavor)
"Ethyl oxyhydrate" (mixture)	(Rum flavor) (I)
Ethyl pelargonate	(Grape flavor, fruit flavor) (III)
Ethyl phenylacetate	(Honey flavor)
Ethyl propionate	(Grape flavor)

Chemical	Example of Use
Ethyl salicylate	(Strawberry flavor)
Ethyl tolylglycidate	(Fruit flavor)
Ethyl valerate	(Fruit flavor) (II)
Ethylvanillin	(Vanilla flavor)
Eucalyptol	(Mint-type flavor)
Eucalyptus oil	(Essential oil, spice flavor)
Eugenol	(Spice flavor) (II)
Furfural	(Butterscotch flavor)
Furfuryl mercaptan	(Coffee flavor)
Geranyl acetate	(Fruit flavor) (III)
Geranyl butyrate	(Pear flavor)
Guaiacol	(Vanilla flavor)
Hexanol	(Apple flavor)
n-Hexyl butyrate	(Apple flavor, pear flavor)
Hydroquinone dimethyl ether	(Nutty flavor)
alpha-Ionone	(Raspberry flavor) (III)
Isoamyl alcohol	(Fruit flavor)
Isoamyl isovalerate	(Fruit flavor)
Isoamyl propionate	(Fruit flavor)
Isobutyl acetate	(Strawberry flavor)
Isobutyl benzoate	(Pineapple flavor)
Isobutyl caproate	(Raisin flavor)
Isobutyl cinnamate	(Pineapple flavor)
Isobutyl propionate	(Fruit flavor)
Isobutyraldehyde	(Nutty flavor)
Isopropyl acetate	(Banana flavor)
Isopropyl isovalerate	(Fruit flavor)
Isopulegol	(Mint flavor)
Isovaleric acid	(Fruit flavor)
Linalool	(Spice flavor) (III)
Linalyl acetate	(Citrus flavor) (IV)
Linalyl cinnamate	(Loganberry flavor)
Linalyl isobutyrate	(Strawberry flavor)
Linalyl valerate	(Loganberry flavor)
Menthol	(Mint flavor) (I)
Menthone	(Mint flavor)
Methadiene-7-carbinol	(Lime flavor)
p-Methoxyacetophenone	(Vanilla-like flavor)
p-Methylacetophenone	(Fruit flavor)
Methyl anthranilate	(Grape flavor) (I)
Methyl benzoate	(Fruit flavor)
Methyl beta-methylthio-propionate	(Pineapple flavor)
Methyl butyrate	(Fruit flavor)
Methyl cinnamate	(Fruit flavor)
Methylcoumarin	(Coconut flavor)
Methylcyclopentanone	(Maple flavor)
a-Methyl furylacrolein	(Cinnamon flavor)
Methylheptenone	(Fruit flavor)
Methyl heptine carbonate	(Strawberry flavor)
Methylionone	(Raspberry flavor)
Methyl isobutyrate	(Fruit flavor)
Methyl isovalerate	(Fruit flavor)
Methyl nonyl ketone	(Orange flavor)
Methyl salicylate	(Root beer flavor, wintergreen flavor) (I)
Methyl phenylacetate	(Honey flavor) (III)

Chemical	Example of Use
Nerol	(Fruit flavor)
Nerol acetate	(Fruit flavor)
Nerol butyrate	(Fruit flavor)
Nerol propionate	(Fruit flavor)
Nerol valerate	(Fruit flavor)
Nonyl alcohol (Alcohol C-9)	(Citrus flavor)
Nonyl aldehyde (Aldehyde C-9)	(Citrus flavor) (IV)
1,4-Nonyl lactone (gamma-Nonylactone)	(Coconut flavor) (II)
Octyl acetate	(Brandy flavor)
Octyl alcohol (Alcohol C-8)	(Citrus flavor)
gamma-Octalactone	(Coconut flavor)
Phenylacetic acid	(Honey flavor)
Phenylbutyl esters	(Honey flavor)
Phenylethyl acetate	(Fruit flavor)
Phenylethyl alcohol	(Fruit flavor)
Phenylethyl butyrate	(Fruit flavor)
Phenylethyl esters	(Honey flavor)
Phenylethyl formate	(Fruit flavor)
Phenylethyl propionate	(Fruit flavor)
Phenylethyl valerate	(Fruit flavor)
Phenylmethyl acetate*	(Fruit flavor)
Phenylmethyl butyrate	(Fruit flavor)
Phenylmethyl carbinol	(Fruit flavor)
Phenylmethyl formate	(Fruit flavor)
Phenylmethyl propionate	(Fruit flavor)
Phenylmethyl valerate	(Fruit flavor)
Phenylpropyl acetate	(Fruit flavor)
Phenylpropyl alcohol	(Fruit flavor)
Phenylpropyl butyrate	(Fruit flavor)
Phenylpropyl esters	(Honey flavor)
Phenylpropyl formate	(Fruit flavor)
Phenyplropyl propionate	(Fruit flavor)
Phenylpropyl valerate	(Fruit flavor)
Piperitone	(Mint flavor)
Piperonal (Heliotropine)	(Vanilla flavor, cherry flavor) (II)
Propenyl guathol (Vanitrope)	(Nutty flavor)
Propyl butyrate	(Fruit flavor)
Propyl cinnamate	(Fruit flavor)
Propyl isobutyrate	(Fruit flavor)
Propyl isocaproate	(Pineapple flavor)
Propyl isovalerate	(Fruit flavor)
Propyl propionate	(Fruit flavor)
"Pyrolignous acid"	(Smoke flavor)
Quinine sulfate	(Bitter agent)
Rhodinyl formate	(Raspberry flavor)
Safrole	(Root beer flavor) (I)
Terpinyl acetate	(Peach flavor)
Thymol	(Spice flavor)
Tolualdehyde	(Cherry flavor)
Tolyl acetate	(Cherry flavor)
Undecyl lactone (gamma-Undecylactone)	(Peach flavor) (II)
Valeric acid	(Butter flavor)
Vanillidene ketone	(Imitation vanilla flavor)
Vanillin	(Vanilla flavor) (I)
Zingerone	(Ginger flavor)

* See Benzyl esters.

Chemical	Example of Use
Artificial Nonnutritive Sweeteners*	
Calcium cyclamate	
Calcium saccharin	
Saccharin	
Sodium cyclamate	
Sodium saccharin	
Flavor enhancers or extenders	
b. Meat	
Monosodium glutamate	Cured meat, corn beef hash, molded steaks, hamburger, luncheon meat, etc.
c. Poultry	
Monosodium glutamate	Precooked frozen and canned poultry
d. Fish and fish products	
Monosodium glutamate	Fish products
g. Fats and oils	
Monosodium glutamate	Mayonnaise, French dressing, salad dressing
h. Fruits and vegetables	
Monosodium glutamate	Canned vegetables, pickles
AGENTS TO IMPROVE FUNCTIONAL PROPERTIES	
Chemicals which affect colloidal properties	
e. Dairy products	
Agar-agar	Ice cream (thickener, stabilizer)
Alginic acid	Cheese (stabilizer)
Calcium chloride	Evaporated milk (stabilizer)
Calcium citrate	Processed cheese (emulsifier)
Carob bean gum	Cheese, chocolate flavored drinks, ice cream, pressure dispensed whipped cream (thickener, stabilizer)
Carragheen (Irish moss derivative)	Cheese, chocolate flavored drinks, ice cream, pressure dispensed whipped cream (emulsifier, stabilizer)
Gelatin	Cheese, chocolate flavored drinks, ice cream (thickener, stabilizer)
Guar gum	Ice cream (thickener, stabilizer)
Gum acacia (gum arabic)	Ice cream (thickener, stabilizer)
Gum karaya	Cheese, ice cream (thickener, stabilizer)
Gum tragacanth	Cheese, ice cream (thickener, stabilizer)
Mono- and di-glycerides	Ice cream (emulsifier)
Oat gum	Processed cheese (thickener, stabilizer)
Pectin	Ice cream (stabilizer)
Polyoxyethylene sorbitan monolaurate	Ice cream, enriched whole milk (emulsifier)
Polyoxyethylene sorbitan monooleate	Ice cream, pressure dispensed whipped cream, enriched whole milk (emulsifier)
Polyoxyethylene sorbitan monostearate	Ice cream, pressure dispensed whipped cream (emulsifier)
Polyoxyethylene sorbitan tristearate	Ice cream (emulsifier)
Polyoxyethylene stearate	Ice cream (emulsifier)
Potassium citrate	Processed cheese (emulsifier)
Potassium phosphate, dibasic	Processed cheese (emulsifier)

* Suggested for use in beverages, canned fruits and vegetables, frozen desserts, jams, jellies, baked goods, salad dressing, frozen fruits.

Chemical	Example of Use
Sodium acid pyrophosphate	Processed cheese (emulsifier)
Sodium alginate	Ice cream, cheese, chocolate flavored drinks, pressure dispensed whipped cream (stabilizer)
Sodium citrate	Cheese, evaporated milk, ice cream, coffee cream (emulsifier, stabilizer)
Sodium metaphosphate	Processed cheese (emulsifier)
Sodium phosphate, dibasic	Processed cheese (emulsifier)
Sodium phosphate, monobasic	Processed cheese (emulsifier)
Sodium phosphate, tribasic	Processed cheese (emulsifier)
Sodium potassium tartrate	Processed cheese (emulsifier)
Sodium tartrate	Processed cheese (emulsifier)
Sorbitan monostearate	Ice cream (emulsifier)
Tetrasodium pyrophosphate	Processed cheese (emulsifier)
f. Eggs	
Invert sugar	Frozen egg yolk (prevent gelation)
Malt syrup	Frozen egg yolk (prevent gelation)
Salt	Frozen egg yolk (prevent gelation)
Sucrose	Frozen egg yolk (prevent gelation)
Triethyl citrate	Improve whipping properties of frozen egg white and egg solids (emulsifier)
g. Fats and oils	
Alginic acid, propylene glycol ester	French dressing, salad dressing (emulsifier)
Carob bean gum	French dressing, salad dressing (emulsifier)
Guar gum	French dressing, salad dressing (emulsifier)
Gum acacia (gum arabic)	French dressing, salad dressing (emulsifier)
Gum karaya	French dressing, salad dressing (emulsifier)
Gum tragacanth	French dressing, salad dressing (emulsifier)
Irish moss, extract	French dressing, salad dressing (emulsifier)
Lecithin	Margarine and shortening (emulsifier)
Mono- and di-glycerides	Margarine and shortening (emulsifier)
Pectin	French dressing, salad dressing (emulsifier)
Sodium carboxymethyl-cellulose	French dressing, salad dressing (emulsifier)
Sodium sulfoacetate of mono- and di-glycerides	Margarine (emlusifier)
h. Fruits and vegetables	
Glycerol monolaurate	Potato granules (surfactant)
Guar gum	Frozen fruit syrup (thickener)
Gum tragacanth	Fruit jellies (stabilizer)
Methyl cellulose	Frozen strawberries, canned dietetic fruits, canned fruit juices (thickener, stabilizer)
Pectin	Frozen strawberries, jellies, jams, preserves, canned dietetic fruits (thickener, stabilizer)
Sodium carboxymethyl-cellulose	Frozen fruits, canned dietetic fruits (thickener, stabilizer)
i. Cereal and cereal products	
Diacetyltartaric acid esters of mono- and di-glycerides of fat-forming fatty acids except lauric acid	Bakery products (emulsifiers)
Mono- and di-glycerides	Bakery products (emulsifiers)
Lecithin	Bakery products (emulsifiers)
Polyoxyethylene sorbitan mono-palmitate	Cakes (emulsifier)
Polyoxyethylene sorbitan mono-stearate	Cakes (emulsifier)
Polyoxyethylene stearate	Sweet rolls, doughnuts (emulsifier)
Sorbitan monostearate	Cakes (emulsifier)
Sorbitan monopalmitate	Cakes (emulsifier)

Chemical	Example of Use
k. Beer	
Gum acacia	(Foam stabilizer)
Hydroxyethyl carboxymethyl-cellulose	(Foam stabilizer)
Methyl cellulose	(Foam stabilizer)
m. Cocoa and chocolate	
Lecithin	Sweet chocolate and milk chocolate (emulsifier)
Mono- and di-glycerides	Sweet chocolate and milk chocolate (emulsifiers)
Monosodium phosphate derivative of mono- and di-glycerides	Sweet chocolate and milk chocolate (emulsifiers)
Firming agents	
h. Fruits and vegetables	
Aluminum sulfate	Pickles
Aluminum potassium sulfate	Pickles
Aluminum sodium sulfate	Pickles
Calcium chloride	Canned tomatoes and potatoes
Calcium citrate	Canned tomatoes and potatoes
Calcium gluconate	Tomatoes and apple slices
Calcium hydroxide	Various fruit products
Calcium sulfate	Canned tomatoes and potatoes
Magnesium chloride	Canned peas
Monocalcium phosphate	Canned tomatoes and potatoes
Maturing agents	
i. Cereal and cereal products	
Calcium peroxide	Bakery products
Chlorine	Bakery products
Chlorine dioxide	Bakery products
Potassium bromate	Bakery products
Potassium iodate	Bakery products

PROCESSING AIDS

For sanitation or esthetic purpose, and for the removal of unwanted covering

b. Meat	
Sodium carbonate	Tripe
Sodium hydroxide	Tripe
Sodium metasilicate	Tripe
Trisodium phosphate	Tripe
Water softener	Processing hogs (scald water)
Wetting agents	Processing hogs (scald water)
c. Poultry	
Chlorine	(Water Supply)
Water softener	(Scald water)
Wax	Duck and geese (feather removal)
Wetting agents	(Scald water)
d. Fish and fish products	
Chlorine	Oysters (wash water)
f. Eggs	
Detergents	Shell eggs
Sodium hydroxide	Shell eggs
Wetting agents	Shell eggs
Sanitizers	Shell eggs

Chemical	Example of Use
h. Fruits and vegetables	
Chlorine	Fruits and vegetables (wash water)
Detergents	Fruits and vegetables (wash water); peas and corn (froth flotation)
Hydrochloric acid	Apples (wash water)
Mineral oil	Peas and corn (froth flotation)
Potassium hydroxide	Peaches, apricots, figs, grapefruit segments (peeling agent)
Sodium carbonate	Peaches, apricots, figs, grapefruit segments (peeling agent)
Sodium hydroxide	Peaches, apricots, figs, grapefruit segments (peeling agent)
Sodium silicate	Apples (wash water)
To control foam	
e. Dairy products	
Dimethyl polysiloxane	Skim milk (antifoam)
h. Fruits and vegetables	
Dimethyl polysiloxane	Jellies, jams, preserves (antifoam in peeling solution)
i. Cereals and cereal products	
Aluminum ammonium sulfate	(Leavening agent)
Aluminum potassium sulfate	(Leavening agent)
Aluminum sodium sulfate	(Leavening agent)
Ammonium bicarbonate	Cookies, crackers (leavening agent)
Ammonium carbonate	Cookies, crackers (leavening agent)
Ammonium phosphate, mono-basic	Cookies, crackers (leavening agent)
Ammonium phosphate, di-basic	Cookies, crackers (leavening agent)
Calcium carbonate	(Leavening agent)
Calcium lactate	(Leavening agent)
Calcium phosphate, mono-basic	(Leavening agent)
Fumaric acid	(Leavening agent)
Glucono-delta-lactone	(Leavening agent)
Potassium acid tartrate	(Leavening agent)
Sodium acid pyrophosphate	(Leavening agent)
Sodium bicarbonate	(Leavening agent)
Tartaric acid	(Leavening agent)
j. Wines	
Dimethyl polysiloxane	(Antifoam during fermentation)
Miscellaneous	
e. Dairy products	
Calcium chloride	Cheese (coagulator)
Ion exchange resins	Milk or cream
Magnesium hydroxide	Cheese (coagulator)
h. Fruits and vegetables	
Sodium chloride	Peas, green beans, and lima beans (solution used to grade)
i. Cereal and cereal products	
Ammonium chloride	(Yeast food)
Ammonium phosphate, mono-basic	(Yeast food)
Ammonium phosphate, di-basic	(Yeast food)
Ammonium sulfate	(Yeast food)
Calcium carbonate	(Yeast food)
Calcium lactate	(Yeast food)
Calcium phosphate, mono-basic	(Yeast food)
Calcium phosphate, di-basic	(Yeast food)
Calcium sulfate	(Yeast food)

Chemical	Example of Use
j. Wines	
Bentonite (clay)	(Clarifying agent)
Casein	(Clarifying agent)
Cufex ($K_2Fe_2(CN)_6$)	(Removal of metal ions)
Diammonium orthophosphate	(Yeast food)
Gelatin	(Clarifying agent)
Isinglass	(Clarifying agent)
Polyvinylpyrrolidone	(Clarifying agent)
Tannin	(Clarifying agent)
Urea	(Yeast food)
k. Beer	
Ammonium phosphate, mono- and di-basic	(Yeast food)
Magnesium sulfate	(Water corrective)
Potassium chloride	(Yeast food)
Potassium phosphate, di-basic	(Yeast food)
Potassium sulfate	(Water corrective)
Polyvinylpyrrolidone	(Clarifying agent)
Tannic acid	(Clarifying agent)
n. Sugar and honey	
Calcium hydroxide	(Refining)
Carbon dioxide	(Refining)
Ion exchange resins	(Refining)
Phosphoric acid	(Refining)
Sulfur dioxide	(Refining)

MOISTURE CONTENT CONTROLS

b. Meat	
Disodium phosphate	Cured pork products (improve water retention properties)
Sodium acid pyrophosphate	Cured pork products (improve water retention properties)
Sodium hexametaphosphate	Cured pork products (improve water retention properties)
Sodium pyrophosphate	Cured pork products (improve water retention properties)
Sodium tripolyphosphate	Cured pork products (improve water retention properties)
e. Dairy products	
Wax	Cheese (wax coating)
f. Eggs	
Mineral oil	Shell eggs (prevent moisture loss)
h. Fruits and vegetables	
Propylene glycol	Shredded coconut (humectant)
Sorbitol	Shredded coconut (humectant)
Wax	Cucumber, eggplant, squashes, peppers, carrots, radishes, melons, potatoes, avocadoes, apples, pears, citrus fruit (prevent moisture loss)
n. Sugar and honey	
Calcium phosphate, tri-basic	(Anticaking agent)
o. Spices	
Calcium phosphate, tri-basic	(Anticaking agent)
Calcium silicate	(Anticaking agent)
Calcium stearate	(Anticaking agent)
Magnesium stearate	(Anticaking agent)

Chemical	Example of Use
CONTROLS FOR ACIDITY AND ALKALINITY	
e. Dairy products	
Acetic acid	Ice cream, processed cheese, cottage cheese
Calcium carbonate	Ice cream
Calcium hydroxide	Ice cream, sour cream, butter
Calcium oxide	Ice cream, sour cream, butter
Calcium phosphate, tri-basic	Ice cream
Citric acid	Sherbet
Lactic acid	Ice cream, processed cheese
Magnesium carbonate	Ice cream, sour cream, butter
Magnesium oxide	Ice cream
Malic acid	Ice cream
Phosphoric acid	Ice cream, processed cheese
Sodium bicarbonate	Ice cream
Sodium carbonate	Ice cream, butter, cream, fluid milk
Sodium citrate	Ice cream, butter, cream, fluid milk
h. Fruits and vegetables	
Acetic acid	Catsup, pickles, canned artichokes
Calcium hydroxide	Canned peas
Citric acid	Canned fruits, canned fruit juices, jellies, jams, preserves
Gluconic acid	Jellies, jams, preserves
Glucono-delta-lactone	Jellies, jams, preserves
Lactic acid	Jellies, jams, preserves
Magnesium carbonate	Canned peas
Magnesium hydroxide	Canned peas
Magnesium oxide	Canned peas
Malic acid	Jellies, jams, preserves
Phosphoric acid	Imitation jellies
Sodium bicarbonate	Tomato paste, canned peas
Sodium carbonate	Canned peas
Sodium citrate	Jellies, jams, preserves
Sodium hydroxide	Process olives
Sodium potassium tartrate	Jellies, jams, preserves
j. Wines	
Calcium carbonate	(Neutralize excess acidity)
Citric acid	(Increase acidity)
Malic acid	(Increase acidity)
Potassium tartrate	(Neutralize excess acidity)
Tartaric acid	(Increase acidity)
k. Beer	
Citric acid	
Hydrochloric acid	
Lactic acid	
Phosphoric acid	
Sulfuric acid	
m. Cocoa and chocolate	
Ammonium bicarbonate	Cocoa and chocolate (improve flavor and darken color) ; breakfast cocoa (improve suspension properties)
Ammonium carbonate	Cocoa and chocolate (improve flavor and darken color) ; breakfast cocoa (improve suspension properties)
Ammonium hydroxide	Cocoa and chocolate (improve flavor and darken color) ; breakfast cocoa (improve suspension properties)

Chemical	Example of Use
Magnesium carbonate	Cocoa and chocolate (improve flavor and darken color) ; breakfast cocoa (improve suspension properties)
Magnesium oxide	Cocoa and chocolate (improve flavor and darken color) ; breakfast cocoa (improve suspension properties)
Potassium bicarbonate	Cocoa and chocolate (improve flavor and darken color) ; breakfast cocoa (improve suspension properties)
Potassium carbonate	Cocoa and chocolate (improve flavor and darken color) ; breakfast cocoa (improve suspension properties)
Potassium hydroxide	Cocoa and chocolate (improve flavor and darken color) ; breakfast cocoa (improve suspension properties)
Sodium bicarbonate	Cocoa and chocolate (improve flavor and darken color) ; breakfast cocoa (improve suspension properties)
Sodium carbonate	Cocoa and chocolate (improve flavor and darken color) ; breakfast cocoa (improve suspension properties)
Sodium hydroxide	Cocoa and chocolate (improve flavor and darken color) ; breakfast cocoa (improve suspension properties)

CONTROLS FOR PHYSIOLOGICAL ACTIVITY

h. Fruits and vegetables	
Carbon dioxide	Stored fruits (retard metabolism)
2,4-Dichlorophenoxyacetic acid	Lemons
Ethylene	Pears, bananas (ripening agent)
Maleic hydrazide	Potatoes and onions (anti-sprouting agent)
Naphthalene acetic acid	Potatoes and onions (anti-sprouting agent)
2,4,5-Trichlorophenoxyacetic acid	Lemons

OTHER AGENTS

e. Dairy products	
Carbon dioxide	Gassed cream (propellant)
Nitrous oxide	Gassed cream (propellant)
Sodium para-toluenesulfochloramine (chloramine T)	(Remove weed odor)
Sorbitol	Dietetic frozen dessert (texturizing agent)
Other food	
Beeswax	Candy (glaze)
Brominated vegetable oils	Soft drinks (flavor carrier)
Caffeine	Soft drink (stimulant)
Carnauba wax	Candy (glaze)
Glycerol	Food colors and flavors (solvent)
Isopropanol	Flavors (solvent)
Kaolin	Dietetic French dressing (adds opaqueness)
Mineral oil	Candy (glaze)
Paraffin	Candy (glaze)
Propylene glycol	Flavors (solvent)
Shellac	Candy (glaze)
Titanium oxide	Candy (pigment)

OFFICIAL LIST OF APPROVED CHEMICALS

Substances Recognized to be Safe Food Additives

Chemicals to be used without specific restrictions under Food, Drug and Cosmetic Act

Chemical preservatives

Ascorbic acid
Ascorbyl palmitate
Calcium ascorbate
Calcium propionate
Erythorbic acid
Potassium sorbate
Calcium sorbate
Propionic acid
Sodium ascorbate
Sodium propionate
Sodium sorbate
Sorbic acid
Tocopherols

Buffers and neutralizing agents

Acetic acid
Aluminum ammonium sulfate
Aluminium sodium sulfate
Aluminum potassium sulfate
Ammonium bicarbonate
Ammonium carbonate
Ammonium hydroxide
Ammonium phosphate (mono- and di-basic-)
Calcium carbonate
Calcium chloride
Calcium citrate
Calcium gluconate
Calcium hydroxide
Calcium lactate
Calcium oxide
Calcium phosphate
Citric acid
Lactic acid
Magnesium carbonate
Adipic acid
Malic acid
Succinic acid
Magnesium oxide
Potassium acid tartrate
Potassium bicarbonate
Potassium carbonate
Potassium citrate
Potassium hydroxide
Sodium acetate
Sodium acid pyrophosphate
Sodium aluminum phosphate
Sodium bicarbonate
Sodium carbonate
Sodium citrate
Sodium hydroxide
Sodium phosphate (mono-, di-, tri-)
Sodium potassium tartrate
Sodium sesquicarbonate
Sulfuric acid
Tartaric acid
Hydrochloric acid
Phosphoric acid

Emulsifying agents

Diacetyl tartaric acid esters of mono- and di-glycerides from the glycerolysis of edible fats or oils.
Mono- and di-glycerides from the glycerolysis of edible fats or oils.
Monosodium phosphate derivatives of mono- and di-glycerides from the glycerolysis of edible fats or oils.
Propylene glycol.

Miscellaneous

Acetic acid
Aluminum sodium sulfate
Aluminum sulfate
Butane
Calcium phosphate, tri-basic
Caramel
Carbon dioxide
Carnauba wax
Citric acid
Glycerin
Glycerol monostearate
Helium
Magnesium carbonate
Ammonium bicarbomate
Beeswax (yellow wax)
Bentonite
Dextrans (of average molecular weight below 100,000)
Monopotassium glutamate
Potassium carbonate
Potassium sulfate
Magnesium hydroxide

Monoammonium glutamate
Nitrogen
Papain
Phosphoric acid
Propane
Propylene glycol
Triacetin
(glyceryl triacetate)
Tricalcium phosphate
Rennet (rennin)
Sodium caseinate
Sodium pectinate
Sodium carbonate
Sodium phosphate
Sodium tripolyphosphate
Ammonium sulfate
Beeswax, bleached (white wax)
Calcium chloride
Methylcellulose (U.S.P. methylcellulose, except that the methoxy content shall not be less than 27.5 per cent and not more than 31.5 per cent on a dry-weight basis)
Sodium bicarbonate
Sodium sesquicarbonate
Torula yeast, dried

Nonnutritive sweeteners

Calcium cyclohexyl sulfamate
Calcium saccharin
Saccharin
Magnesium cholohexyl sulfamate
Sodium cyclohexyl sulfamate
Sodium saccharin
Ammonium saccharin
Potassium cyclohexyl sulfamate

Nutrients

Ascorbic acid
Calcium carbonate
Calcium oxide
Calcium pantothenate
Calcium phosphate
(mono-, di-, tri-basic)
Calcium sulfate
Carotene
Ferric phosphate
Ferric pyrophosphate
Ferric sodium pyrophosphate
Ferrous sulfate
Iron, reduced
l-Lysine monohydrochloride
Niacin
Niacinamide
D-Pantothenyl alcohol
Inositol
Potassium chloride
Pyridoxine hydrochloride
Riboflavin
Riboflavin-5-phosphate
Sodium pantothenate
Sodium phosphate
(mono-, di-, tri-basic)
Thiamine hydrochloride
Thiamine mononitrate
a-Tocopherol acetate
Vitamin A
Vitamin A acetate
Vitamin A palmitate
Vitamin B_{12}
Vitamin D_2
Vitamin D_3
Choline bitartrate

Sequestrants

(For the purpose of this list, no attempt has been made to designate those sequestrants which may also function as chemical preservatives)

Calcium acetate
Calcium chloride
Calcium citrate
Calcium diacetate
Calcium gluconate
Calcium hexametaphosphate
Calcium phytate
Citric acid
Dipotassium phosphate
Disodium phosphate
Monocalcium acid phosphate
Monoisopropyl citrate
Potassium citrate
Sodium acid phosphate
Sodium citrate
Sodium diacetate
Sodium gluconate
Sodium hexametaphosphate
Sodium metaphosphate
Sodium phosphate
(mono-, di-, tri-basic)
Sodium potassium tartrate
Sodium pyrophosphate
Sodium tartrate
Sodium tetrapyrophosphate
Sodium tripolyphosphate
Tartaric acid

Stabilizers

Agar-agar
Carob bean gum (locust bean gum)
Ammonium alginate
Ghatti gum
Sodium alginate
Tragacanth (gum tragacanth)
Carragheenin
Guar gum
Acacia (gum Arabic)
Calcium alginate
Potassium alginate
Sterculia gum (karaya gum)

Spices and other natural seasonings and flavorings approved for use under Food, Drug and Cosmetic Act

COMMON NAME	BOTANICAL NAME OF PLANT SOURCE
Allspice	*Pimenta officinalis* Lindl.
Anise	*Pimpinella anisum* L.
Anise, star	*Illicium verum* Hook. f.
Basil, sweet	*Ocimum basilicum* L.
Basil, bush	*Ocimum minimum* L.
Bay	*Laurus nobilis* L.
Calendula	*Calendula officinalis* L.
Capers	*Capparis spinosa* L.
Capsicum	*Capsicum frutescens* L. or *Capsicum annuum* L.
Caraway	*Carum carvi* L.
Caraway, black (black cumin)	*Nigella sativa* L.
Cardamom (cardamon)	*Elettaria cardamomum* Maton.
Cassia, Chinese	*Cinnamomum cassia* Blume.
Cassia, Padang or Batavia	*Cinnamomum burmanni* Blume.
Cassia, Saigon	*Cinnamomum loureirii* Nees.
Cayenne pepper	*Capsicum frutescens* L. or *Capsicum annuum* L.
Celery seed	*Apium graveolens* L.
Chives	*Allium schoenoprasum* L.
Cinnamon, Ceylon	*Cinnamomum zeylanicum* Nees.
Cinnamon, Chinese	*Cinnamomum cassia* Blume.
Cinnamon, Saigon	*Cinnamomum loureirii* Nees.
Clary (clary sage)	*Salvia sclarea* L.
Cloves	*Eugenia caryophyllata* Thunb.
Coriander	*Coriandrum sativum* L.
Cumin (cummin)	*Cuminum cyminum* L.
Cumin, black (black caraway)	*Nigella sativa* L.
Dill	*Anethum graveolens* L.
Fennel, common	*Foeniculum vulgare* Mill.
Fennel, sweet (finocchio, Florence fennel)	*Foeniculum vulgare* Mill. var. *dulce* (DC.) Alef.
Fenugreek	*Trigonella foenum-graecum* L.
Garlic	*Allium sativum* L.
Ginger	*Zingiber officinale* Rosc.
Glycyrrhiza	*Glycyrrhiza glabra* L. and other spp. of *Glycyrrhiza*
Grains of paradise	*Amomum melegueta* Rosc.
Horseradish	*Armoracia lapathifolia* Gilib.
Lavender	*Lavandula officinalis* Chaix.
Licorice	*Glycyrrhiza glabra* L. and other spp. of *Glycyrrhiza*
Mace	*Myristica fragans* Houtt.
Marigold, pot	*Calendula officinalis* L.

COMMON NAME	BOTANICAL NAME OF PLANT SOURCE
Marjoram, pot	*Majorana onites* (L.) Benth.
Marjoram, sweet	*Majorana hortensis* Moench.
Mustard, black or brown	*Brassica nigra* (L.) Koch.
Mustard, brown	*Brassica juncea* (L.) Coss.
Mustard, white or yellow	*Brassica alba* (L.) Boiss.
Nutmeg	*Myristica fragrans* Houtt.
Oregano (oreganum, Mexican oregano, Mexican sage, origan)	*Lippia* spp.
Paprika	*Capsicum annum* L.
Parsley	*Petroselinum crispum* (Mill.) Mansf.
Pepper, black	*Piper nigrum* L.
Pepper, cayenne	*Capsicum frutescens* L. or *Capsicum annum* L.
Pepper, red	Do.
Pepper, white	*Piper nigrum* L.
Peppermint	*Mentha peperita* L.
Poppy seed	*Papaver somniferum* L.
Pot marigold	*Calendula officinalis* L.
Pot marjoram	*Majorana onites* (L.) Benth.
Rosemary	*Rosmarinus officinalis* L.
Rue	*Ruta graveolens* L.
Saffron	*Crocus sativus* L.
Sage	*Salvia officinalis* L.
Savory, summer	*Satureia hortensis* L. (Satureja)
Savory, winter	*Satureia montana* L. (Satureja)
Sesame	*Sesamum indicum* L.
Spearmint	*Mentha spicata* L.
Star anise	*Illicium verum* Hook. f.
Tarragon	*Artemisia dracunculus* L.
Thyme	*Thymus vulgaris* L.
Turmeric	*Curcuma longa* L.
Vanilla	*Vanilla planifolia* Andr. or *V. tahitensis* J. W. Moore
Zedoary	*Curcuma zedoaria* Rosc.

Chemicals to be used with restrictions under Food, Drug and Cosmetic Act

PRODUCT	TOLERANCE	SPECIFIC USES OR RESTRICTIONS
ANTICAKING AGENTS		
Aluminum calcium silicate	2 per cent	In table salt
Calcium silicate	5 per cent	In baking powder
Calcium silicate	2 per cent	In table salt
Magnesium silicate	2 per cent	In table salt
Tricalcium silicate	2 per cent	In table salt
Sodium aluminosilicate	2 per cent	
Sodium calcium aluminosilicate, hydrated	2 per cent	
CHEMICAL PRESERVATIVES		
Benzoic acid	0.1 per cent	
Butylated hydroxyanisole	Total content of antioxidants not over 0.02 per cent of fat or oil content, including essential (volatile) oil content, of food.	
Butylated hydroxytoluene	do.	

PRODUCT	TOLERANCE	SPECIFIC USES OR RESTRICTIONS
Caprylic acid		In cheese wraps
Dilauryl thiodipropionate	Total content of antioxidants not over 0.02 per cent of fat or oil content, including essential (volatile) oil content of the food.	
Gum guaiac	0.1 per cent (equivalent antioxidant activity 0.01 per cent)	In edible fats or oils
Nordihydroguaiaretic acid	Total content of antioxidants not over 0.02 per cent of fat or oil content, including essential (volatile) oil content of the food.	
Potassium bisulfate		Not in meats or in food recognizable as a source of Vitamin B_1.
Potassium metabisulfate		Not in meats or in food recognizable as a source of Vitamin B_1.
Propyl gallate	Total content of antioxidants not over 0.02 per cent of fat or oil content, including essential (volatile) oil content of the food.	
Sodium benzoate	0.1 per cent	
Sodium bisulfite		Not in meats or in food recognizable as a source of Vitamin B_1.
Sodium metabisulfate		do
Sodium sulfite		do
Sulfur dioxide		do
Thiodipropionic acid	Total content of antioxidants not over 0.02 per cent of fat or oil content, including essential (volatile) oil content of the food.	
Methylparaben (methyl-*p*-hydroxybenzoate)	0.1 per cent	
Propylparaben (propyl-*p*-hydroxybenzoate)	0.1 per cent	
Stannous chloride	0.0015 per cent, calculated as tin	
EMULSIFYING AGENTS		
Cholic acid	0.1 per cent	Dried egg whites
Dexoxycholic acid	0.1 per cent	Dried egg whites
Glycocholic acid	0.1 per cent	Dried egg whites
Ox bile extract	0.1 per cent	Dried egg whites
Taurocholic acid (or its sodium salt)	0.1 per cent	Dried egg whites

PRODUCT	TOLERANCE	SPECIFIC USES OR RESTRICTIONS
MISCELLANEOUS		
Caffeine	0.02 per cent	In cola type beverages
Ethyl formate	0.0015 per cent	As fumigant for cashew nuts
Magnesium stearate		As migratory substance from packaging materials when used as a stabilizer.
Glutamic acid		Salt substitute
Glutamic acid hydrochloride		Salt substitute
Hydrogen peroxide		Bleaching agent
Mannitol	5 per cent	In special dietary foods.
Nitrous oxide		Propellant for certain dairy and vegetable fat toppings in pressurized containers.
Silica aerogel (finely powdered microcellular silica foam having a minimum silica content of 89.5 per cent)		Component of anti-foaming agent.
Sorbitol	7.0 per cent	In foods for special dietary use.
Triethyl citrate	0.25 per cent	Egg whites
NUTRIENTS		
Copper gluconate	0.005 per cent	
Cuprous iodide	0.01 per cent	In table salt as a source of dietary iodine.
Potassium iodide	0.01 per cent	Same as above.
Glycine (amino acetic acid)		Animal feeds
SEQUESTRANTS*		
Isopropyl citrate	0.02 per cent	
Sodium thiosulfate	0.1 per cent	In salt
Stearyl citrate	0.15 per cent	
Activated charcoal complying with specifications of The National Formulary, 10th Edition	0.4 per cent	Pigment in food processing.
Carbon black prepared by the "imgingement" or "channel" process	0.4 per cent	Pigment in food processing.

Essential oils, oleoresins (solvent-free), and natural extractives (including distillates) approved for use under Food, Drug and Cosmetic Act

COMMON NAME	BOTANICAL NAME OF PLANT SOURCE
Allspice	*Pimenta officinalis* Lindl.
Almond, bitter (free from prussic acid)	*Prunus amygdalus* Batsch, *Prunus armeniaca* L., or *Prunus persica* (L.) Batsch.
Angelica root	*Angelica archangelica* L.
Angelica seed	*Angelica archangelica* L.
Angelica stem	*Angelica archangelica* L.
Angostura (cusparia bark)	*Galipea officinalis* Hancock
Anise	*Pimpinella anisum* L.

* For the purpose of this list no attempt has been made to designate those sequestrants which may also function as chemical preservatives.

COMMON NAME	BOTANICAL NAME OF PLANT SOURCE
Asafetida	*Ferula assa-foetida* L. and related spp. of *Ferula.*
Balsam of Peru	*Myroxylon pereirae* Klotzsch.
Basil	*Ocimum basilicum* L.
Bay leaves	*Laurus nobilis* L.
Bay (myrcia oil)	*Pimenta racemosa* (Mill.) J. W. Moore.
Bitter almond (free from prussic acid)	*Prunus amygdalus* Batsch, *Prunus armeniaca* L., or *Prunus persica* (L.) Batsch.
Bois de rose	*Aniba rosaeodora* Ducke.
Cananga	*Cananga odorata* Hook. f. and Thoms.
Capsicum	*Capsicum frutescens* L. and *Capsicum annum* L.
Caraway	*Carum carvi* L.
Cardamom seed (cardamon)	*Elettera cardamomum* Maton
Carob bean	*Ceratonia siliqua* L.
Cascarilla bark	*Croton eluteria* Benn.
Cassia bark, Chinese	*Cinnamomum cassia* Blume
Cassia bark, Padang or Batavia	*Cinnamomum burmanni* Blume
Cassia bark, Saigon	*Cinnamomum loureirii* Nees.
Celery seed	*Apium graveolens* L.
Chamomile flowers, Hungarian (camomile)	*Matricaria chemomilla* L.
Chamomile flowers, Roman or English (camomile)	*Anthemis nobilis* L.
Cherry, wild, bark	*Prunus serotina* Ehrh.
Chicory	*Chicorium intybus* L.
Cinnamon bark, Ceylon	*Cinnamomum zeylanicum* Nees.
Cinnamon bark, Chinese	*Cinnamomum cassia* Blume.
Cinnamon bark, Saigon	*Cinnamomum loureirii* Nees.
Cinnamon leaf, Ceylon	*Cinnamomum zeylanicum* Nees.
Cinnamon leaf, Chinese	*Cinnamomum cassia* Blume.
Cinnamon leaf, Saigon	*Cinnamomum loureirii* Nees.
Citronella	*Cymbopogon nardus* Rendle.
Citrus peels	*Citrus* spp..
Clary (clary sage)	*Salvia sclarea* L.
Clove bud	*Eugenia caryophyllata* Thunb.
Clove leaf	do.
Clove stem	*Eugenia caryophyllata* Thunb.
Coca (decocainized)	*Erythroxylum coca* Lam. and other.
Coffee	*Coffea* spp., spp. of *Erythroxylum.*
Cola nut	*Cola acuminata* Schott and Endl., and other spp. of *Cola*
Coriander	*Coriandrum sativum* L.
Cumin (cummin)	*Cuminum cyminum* L.
Cusparia bark	*Calipea officinalis* Hancock.
Dill	*Anethum graveolens* L.
Estragole (esdragol, esdragon, tarragon)	*Artemisia dracunculus* L.
Fennel, sweet	*Foeniculum vulgare* Mill.
Fenugreek	*Trigonella foenum-graecum* L.
Garlic	*Allium sativum* L.
Geranium, East Indian	*Cymbopogon martini* Stapf.
Geranium, rose	*Pelargonium graveolens* L'Her.
Ginger	*Zingiber officinale* Rose.
Glycyrrhiza	*Glycyrrhiza glabra* L. and other spp. of *Glycyrrhiza.*
Grapefruit	*Citrus paradisi.*
Guava	*Psidium* spp.
Hoarhound	*Marrubium vulgare* L.
Hops	*Humulus lupulus* L.

COMMON NAME	BOTANICAL NAME OF PLANT SOURCE
Jasmine	*Jasminum officinale* L. and other spp. of *Jasminum.*
Juniper (berries)	*Juniperus communis* L.
Kola nut	*Cola acuminata* Schott and Endl., and other spp. of *Cola.*
Laurel leaves	*Laurus obilis* L.
Lavender	*Lavandula officinalis* Chaix.
Lavender, spike	*Lavandula latifolia* Vill.
Lavandin	Hybrids between *Lavandula officinalis* Chaix and *Lavandula latifolia* Vill.
Lemon	*Citrus limon* (L.) Burm. f.
Lemon grass	*Cymbopogon citratus* DC. and *Cymbopogon flexuosus* Stapf.
Licorice	*Glycyrrhiza glabra* L. and other spp. of *Glycyrrhiza.*
Lime	*Citrus aurantifolia* Swingle.
Locust bean	*Ceratonia siliqua* L.
Mace	*Myristica fragrans* Houtt.
Mandarin	*Citrus reticulata* Blanco.
Marjoram, sweet	*Majorana hortensis* Moench.
Maté	*Ilex paraguariensis* St. Hil.
Mustard	*Brassica* spp.
Maringin	*Citrus paradisi* Macf.
Neroli, bigarade	*Citrus aurantium* L.
Nutmeg	*Myristica fragrans* Houtt.
Onion	*Allium cepa* L.
Orange, bitter, flowers	*Citrus aurantium* L.
Orange, leaf	*Citrus sinensis* (L.) Osbeck.
Orange, bitter, peel	*Citrus aurantium* L.
Orange, sweet	*Citrus sinensis* (L.) Osbeck.
Origanum	*Origanum* spp.
Palmarosa	*Cymbopogon martini* Stapf.
Paprika	*Capsicum annuum* L.
Parsley	*Petroselinum crispum* (Mill.) Mansf.
Pepper, black	*Piper nigrum* L.
Pepper, white	*Piper nigrum* L.
Peppermint	*Mentha piperita* L.
Peruvian balsam	*Myroxylon pereirae* Klotzsch.
Petitgrain	*Citrus aurantium* L.
Petitgrain lemon	*Citrus limon* (L.) Burm. f.
Petitgrain mandarin or tangerine	*Citrus reticulata* Blanco.
Pimenta	*Pimenta officinalis* Lindl.
Pimenta leaf	*Pimenta officinalis* Lindl.
Pipsissewa leaves	*Chimaphila umbellata* Nutt.
Pomegranate	*Punica granatum* L.
Prickly ash bark	*Xanthoxylum* (or *Zanthoxylum*) *americanum* Mill. or *Xanthoxylum clava-herculis* L.
Rose absolute	*Rosa alba* L., *Rosa centifolia* L., *Rosa damascena* Mill., *Rosa gallica* L., and vars. of these spp.
Rose (otto of roses, attar of roses)	Do.
Rose geranium	*Pelargonium graveolens* L'Her.
Rosemary	*Rosmarinus officinalis* L.
Rue	*Ruta graveolens* L.
Saffron	*Crocus sativus* L.
Sage	*Salvia officinalis* L.
Sage, Spanish	*Salvia lavandulaefolia* Vahl.
St. John's bread	*Ceratonia siliqua* L.

COMMON NAME	BOTANICAL NAME OF PLANT SOURCE
Schinus molle	*Schinus molle* L.
Spanish sage	*Salvia lavandulaefolia* Vahl.
Spearmint	*Mentha spicata* L.
Spike lavender	*Lavandula latifolia* Vill.
Tangerine	*Citrus reticulata* Blanco.
Tarragon	*Artemisia dracunculus* L.
Tea	*Thea sinensis* L.
Thyme	*Thymus vulgaris* L. and *Thymus zygis* var. *gracilis* Boiss.
Thyme, white	Do.
Tuberose	*Polianthes tuberosa* L.
Turmeric	*Curcuma longa* L.
Vanilla	*Vanilla planifolia* Andr. or *Vanilla tahitensis* J. W. Moore.
Violet leaves absolute	*Viola odorata* L.
Wild cherry bark	*Prunus serotina* Ehrh.
Ylang-ylang	*Cananga odorata* Hook. f. and Thoms.
Zedoary bark	*Curcuma zedoaria* Rosc.

Miscellaneous flavoring agents approved for use under Food, Drug and Cosmetic Act

COMMON NAME	DERIVATION
Civet (zibeth, zibet, zibetum)	Civet cats, *Vivera civetta* Schreber and *Viverra zibetha* Schreber.
Cognac oil, white and green	Ethyl oenanthate, so-called.
Musk (Tonquin musk)	Musk deer, *Moschus moschiferus* L.

Substances approved for use in the manufacture of food-packaging materials under Food, Drug and Cosmetic Act

Antioxidants (limit of addition to food, 0.005 per cent)

Butylated hydroxyanisole
Butylated hydroxytoluene
Dilauryl thiodipropionate
Distearyl thiodipropionate
Gum Guaiac
Nordihydroguaiaretic acid
Propyl gallate
Thiodipropionic acid
2,4,5-Trihydroxy butyrophenone

Antimycotics

Calcium propionate
Methylparaben (methyl *p*-hydroxybenzoate)
Propylparaben (propyl *p*-hydroxybenzoate)
Sodium benzoate
Sodium propionate
Sorbic acid

Driers

Cobalt caprylate
Cobalt linoleate
Cobalt naphthenate
Cobalt tallate
Iron caprylate
Iron linoleate
Iron naphthenate

Iron tallate
Manganese caprylate
Manganese linoleate
Manganese naphthenate
Manganese tallate

Drying oils (as components of finished resins)

Chinawood oil (tung oil)
Dehydrated castor oil
Linseed oil
Tall oil

Plasticizers

Acetyl tributyl citrate
Acetyl triethyl citrate
p-tert-Butylphenyl salicylate
Butyl stearate
Butylphthalyl butyl glycolate
Dibutyl sebacate
Diethyl phthalate
Diisobutyl adipate
Diisooctyl phthalate (for foods of high water content only)
Diphenyl-2-ethylhexyl phosphate
di-(2-Ethylhexyl) phthalate (for foods of high water content only)
Epoxidized soybean oil (iodine number maximum 6; and oxirane oxygen, minimum, 6.0 per cent)
Ethylphthalyl ethyl glycolate
Glycerol monooleate
Monoisopropyl citrate
Mono-, di-, and tri-stearyl citrate
Triacetin (glycerol triacetate)
Triethyl citrate
3-(2-Xenoyl)-1,2-epoxypropane

Release agents

Dimethylpolysiloxane (substantially free from hydrolyzable chloride and alkoxy groups, no more than 18 per cent loss in weight after heating 4 hours at 200° C.; viscosity 300 centistokes, 600 centistokes at 25° C., specific gravity 0.96 to 0.97 at 25° C., refractive index 1.400 to 1.404 at 25° C.).

Linoleamide (linoleic acid amide)
Oleamide (oleic acid amide)
Palmitamide (palmitic acid amide)
Polyethylene glycol 400
Polyethylene glycol 1500
Polyethylene glycol 4000
Stearamide (stearic acid amide)

Stabilizers

Aluminum mono-, di-, and tri-stearate
Ammonium citrate
Ammonium potassium hydrogen phosphate
Calcium acetate
Calcium carbonate
Calcium glycerophosphate
Calcium phosphate
Calcium hydrogen phosphate
Calcium oleate
Calcium ricinoleate
Calcium stearate
Disodium hydrogen phosphate
Magnesium glycerophosphate

Magnesium stearate
Magnesium phosphate
Magnesium hydrogen phosphate
Mono-, di-, and tri-sodium citrate
Mono-, di-, and tri-potassium citrate
Potassium oleate
Potassium stearate
Sodium pyrophosphate
Sodium stearate
Sodium tetrapyrophosphate
Tin stearate (not to exceed 50 parts per million tin as a migrant in finished food)
Zinc orthophosphate (not to exceed 50 parts per million zinc as a migrant in finished food)
Zinc resinate (not to exceed 50 parts per million zinc as a migrant in finished food)

Chemicals approved for use under Federal Meat Inspection Act

ADDITIVE	PURPOSE	PRODUCTS	AMOUNT
Acetic acid	Refining	Rendered fats	Sufficient for purpose
Methyl polysilicone	To retard foaming	Soup	10 ppm
Ascorbic acid	Accelerate color fixing in curing	Cured cuts; cured comminuted product	7½ ozs. to 100 gals. pickle; ¾ oz. to 100 lbs. meat
Bacterial starter; lactic acid starter culture	To develop flavor	Dry sausage; pork roll	0.5%
Benzoate, sodium; benzoic acid	To retard flavor reversion	Oleomargarine	0.1%
Butylated hydroxyanisole	Antioxidant: to retard rancidity development	Lard and shortening	0.01%
Butylated hydroxyanisole	Antioxidant: to retard rancidity development	Unsmoked dry sausage	0.003%
Butylated hydroxytoluene	Antioxidant: to retard rancidity development	Lard and shortening	0.01%
Bicarbonate of soda	To neutralize excess acidity; cleaning vegts.	Rendered fats; tomato soup; beans, etc.	Sufficient for purpose
Borax	Preservative	Export	Sufficient for purpose
Bromelin	Same use as papain		
Carbon (purified charcoal)	Refining	Rendered fat	Sufficient for purpose
Carbon dioxide gas	Immobilizing	Hogs	Sufficient for purpose
Cardomate, sodium	Binder and extender	Imitation sausage; non-specific loaves; soups; stews; etc.	Sufficient for purpose
Caustic soda (sodium hydroxide)	Refining; denuding	Fats; tripe	Sufficient for purpose
Cellulose gum (carboxymethyl cellulose)	Extender, stabilizer	Baked pies, etc.	Sufficient for purpose
Citric acid	Synergist: to increase effectiveness of antioxidants	Lard and shortening	0.01%
Citric acid	Synergist: to increase effectiveness of antioxidants	Unsmoked dry sausage	0.01%
Citric acid	To protect flavor	Oleomargarine	Sufficient for purpose
Citric acid	Flavoring	Chili con carne	Sufficient for purpose
Citric acid and sodium citrate	Prevent coagulation	Beef blood	0.2%

ADDITIVE	PURPOSE	PRODUCTS	AMOUNT
Coloring material, vegetable, and synthetic	To color casings, rendered fat, marking ink, etc.	Sausage casings; oleomargarine; shortening; branding ink	Sufficient for purpose
Corn syrup	Flavor; cure	Cured product; hamburger	2.5%
Corn syrup, dried	Flavor; cure	Cured product; hamburger	2.0%
Cyclamate, sodium	Sweetener	Bacon	0.15%
Cyclohexylamine	To retard corrosion	Boiler water	10 ppm from approved feeder
Dextrose	Flavor; cure; seasoning	Sausage, ham, etc.	Sufficient for purpose
Diacetyl	Flavor	Oleomargarine	Sufficient for purpose
Diatomaceous earth	Refining	Rendered fats	Sufficient for purpose
Dry ice (carbon dioxide-solid)	Cooling	Chopping of meat; packaging of product	Sufficient for purpose
Ficin	Same use as papain		
Fullers earth	Refining	Rendered fats	Sufficient for purpose
Glycerol	Inhibit drying; manufacture of mono- & di-glycerides	Seasonings, curing mixes	Sufficient for purpose
Glycerol lacto-palmitate, etc.	A type of mono- & di-glycerides	Shortening	Sufficient for purpose
Gums, vegetable (tragacanth, karaya, etc.)	Emulsifying agent; binder	Spice emulsion; egg roll, breading mix	Sufficient for purpose
Hydrogen peroxide	Bleach	Tripe	Sufficient for purpose
Hydrolyzed plant protein	Flavor	Various	Sufficient for purpose
Isoascorbic acid	Accelerate color fixing in curing	Cured cuts; cured comminuted product	7½ ozs. to 100 gals. pickle; ¾ oz. to 100 lbs. meat
Isopropyl citrates	To protect flavor	Oleomargarine	0.02%
Lecithin	To retard rancidity development; emulsifier	Lard and shortening	Sufficient for purpose
Lecithin	Emulsifier	Oleomargarine	0.5%
Lignin	Loosen scale	Steam boilers	Sufficient for purpose
Lime	Denude	Tripe	Sufficient for purpose
Malt syrup	Flavor; cure	Cured product	2.5%
Mono-and di-glycerides	Emulsifiers	Lard, shortening, oleomargarine	Sufficient for purpose, 0.5% in oleomargarine
Monoisopropyl citrate	To increase effectiveness of antioxidants	Lard, shortening; oleomargarine	0.01% in lard & shortening; 0.02% in oleomargarine
Monosodium glutamate	Flavor	Various	Sufficient for purpose
Morpholine	To retard corrosion	Boiler water	10 ppm from approved feeder
Nickel	Catalyst	Hydrogenated fats	Sufficient for purpose
Nitrate of soda or potassium	Source of nitrite	Cured products	See sodium or potassium nitrate
Nitrite of soda or potassium	Fix color	Cured products	See sodium or potassium nitrite
Nitrogen	Exclude oxygen	Sealed products	Sufficient for purpose
Nordhydro-guaiaretic acid	Antioxidant: To retard rancidity development	Lard and shortening	0.01%

ADDITIVE	PURPOSE	PRODUCTS	AMOUNT
Octadecylamine	Boiler additive to retard corrosion in steam pipes	Steam	2.5 ppm in condensed steam (analysis required)
Papain	Soften tissue	Frozen cuts	Sufficient for purpose
Phosphates: disodium; sodium hexameta-; tripoly-; sodium pyro-; sodium acid pyrophosphate	Decrease amount of cooked-out juices	Ham, pork, shoulder picnic; canned chopped ham	5.0% in pumping pickle; 0.5% in canned chopped ham
Phosphate, sodium hexameta-	Retard scale formation in pipes	Potable water supply	10 ppm from approved feeder
Phosphate, trisodium	Denuder	Tripe	Sufficient for purpose
Phosphoric acid	Synergist: to increase effectiveness of antioxidants	Lard and shortening	0.01%
Propyl gallate	Antioxidant: To retard rancidity development	Lard and shortening	0.01%
Resin guaiac	Antioxidant: To retard rancidity development	Lard and shortening	0.1%
Silica gel	Anti-caking agent	Curing mixes, etc.	0.5%
Sodium ascorbate; sodium isoascorbate	Accelerate color fixing in curing	Cured cuts; cured comminuted product	7½ ozs. to 100 gals. pickle; ⅞ oz. to 100 lbs. meat; 10% soln. to surface of cured product prior to packaging
Sodium carbonate	Refining; denuding	Fats; tripe	Sufficient for purpose
Sodium caseinate	Binder & extender	Imitation sausage; non-specific loaves; soups; stews; etc.	Sufficient for purpose
Sodium hydroxide	Denuder	Tripe	Sufficient for purpose
Sodium metasilicate	Denuder	Tripe	Sufficient for purpose
Sodium or potassium nitrate	Source of nitrite	Cured products	7 lbs to 100 gals. pickle; 3½ ozs. to 100 lbs. meat (dry cure); 2¾ ozs. to 100 lbs. chopped meat
Sodium or potassium nitrite	Color fixing	Cured products	200 ppm (.02%) in product; 2 lbs. to 100 gals. pickle; 1 oz. to 100 lbs. meat (dry cure); ¼ oz. to 100 lbs. chopped meat
Sodium sulfoacetate derivatives of mono- and di-glycerides	Emulsifier	Oleomargarine	0.5%
Sorbitol	Retard drying	Seasonings	Sufficient for purpose
Starter distillate	Flavor	Oleomargarine	Sufficient for purpose
Stearyl citrate	To protect flavor	Oleomargarine	0.15%
Sugars, approved (sucrose and dextrose)	Flavoring; curing; seasoning	Sausage, ham, miscellaneous	Sufficient for purpose
Sulfites with strong alkali	Retard corrosion	Boiler water	Sufficient for purpose
Tannic acid	Refining; loosen scale	Rendered fats; boiler water	Sufficient for purpose
Tocopherols	Antioxidant: to retard rancidity development	Lard and shortening	0.03%

Synthetic resins, plasticizers, stabilizers, driers, drying oils, colorants and release agents approved for use in rubber or synthetic resin plastics intended for contact with federally inspected meat food product.

RESINS

Can enamels

The classes of resins that have been met with most frequently are:
Bisphenol-epichlorhydrin
Bisphenol-epichlorhydrin esters
Epoxy ester
Bisphenol-epichlorhydrin-vinyl
Certain modified phenols
Certain modified vinyls
Oleoresins
Alkyl oleoresinous
Polyester
Alkyl ester

The basic types of resins may be listed as follows:

Fossil resins, specifically gilsonite, and natural East Indian and Congo resins
Bisphenol-formaldehyde
Certain substituted phenol formaldehydes
Phenol formaldehyde
Urea formaldehyde
Bisphenol-epichlorhydrin
Bisphenol-epichlorhydrin esters
Haleic anhydride resin ester
Esterified Congo resin
Esterified resin
Melamine-formaldehyde
Polyvinyl chloride and acetate
Cellulose acetate butyrate
Polystyrene
Polyvinyl butyral
Polyethylene
Petroleum hydrocarbon

Films for wrapping foods

The acceptable resins for wrapping foods are:
Condensate of dimethyl terephthalate and ethylene glycol
Resins from high and low viscosity polyvinyl alcohol for fatty foods only
Polyvinyl chloride
Polyvinyl acetate
Polyvinyl chloride-acetate
Vinylidine chloride
Polystyrene
Polyethylene of the high and low pressure type
Cellulose acetate
Regenerated cellulose
Butadiene-scrylonitrile synthetic rubber
Methyl and ethyl acrylate
Ethyl cellulose
Rubber hydrochloride
Polyester resin-ethylene terephthalate and ethylene isophthalate
Butadiene acrylonitrile-styrene copolymer
Butadiene-styrene copolymer
Terephthalic acid-ethylene glycol copolymer

Grease-proofing and wet-strength resins for paper wraps:

Polymer of 2-chloro-butadiene
Polymer of melamine-formaldehyde
Polymer of urea-formaldehyde
Polymer of dimethyl-polysiloxane of 350 centistokes viscosity
Copolymer of styrene and iso-butylene (for foods of high water content only)

PLASTICIZERS

Acetyl tributyl citrate
Acetyl triethyl citrate
Butyl stearate
Butyl phthalyl butyl glycollate
p-Tertiary butyl phenyl salicylate
Dibutyl sebacate
Di-iso butyl adipate
Di-2-ethylhexyl phthalate (for foods of high water content only)
Di-iso-octyl phthalate (for foods of high water content only)
Diethyl phthalate
2-Ethylhexyl diphenyl phosphate
Ethyl phthalyl ethyl glycollate
Glyceryl monooleate
Glycerin triacetate
Monisopropyl citrate
Paraplex G-60
Paraplex G-62
Stearyl citrate
Triethyl citrate
3-(2-Xenoxyl)-1,2-epoxypropane

STABILIZERS

Aluminum monostearate
Ammonium citrate
Ammonium potassium phosphate
Calcium acetate
Calcium ethyl acetoacetate acetate
Calcium carbonate
Calcium glycerophosphate
Mono-, di- and tri-calcium phosphate
Calcium oleate
Calcium ricinoleate
Calcium stearate
Magnesium glycerophosphate
Magnesium stearate
Mono-, di- and tri-magnesium phosphate
Potassium citrate
Disodium hydrogen phosphate
Sodium citrate
Sodium pyrophosphate
Sodium tetrapyrophosphate
Tin stearate
Inorganic salts of copper-manganese, and zinc, zinc stearate and zinc resinate, are acceptable if the leaching of the metal contributes less than 50 parts per million to the food.

DRIERS

Cobalt caprylate, linolate, naphthenate, and tallate
Iron caprylate, linoleate, naphthenate, and tallate
Manganese caprylate, linoleate, naphthenate, and tallate

DRYING OILS

Chinawood oil
Dehydrated castor oil
Linseed oil
Tall oil

COLORANTS (Pigments)

Carbon black
Oxides of iron
Titanium dioxide (National Formulary grade)
Ultramarine blue

RELEASE AGENTS

Acrowax
DC Fluid 200 of 60,000 centistokes viscosity
Methyl polysiloxane of 350 centistokes viscosity
Microcrystalline wax
Linoleic acid amide
Oleic acid amide
Palmitic acid amide
Stearic acid amide
Polyethylene glycol 400
Polyethylene glycol 1500
Polyethylene glycol 4000
Polytetrafluoroethylene

Chemicals approved for use under Federal Poultry Products Inspection Act

ADDITIVE	PURPOSE	AMOUNT
Acetic acid	Refining	Sufficient for purpose
Amines, filming	Volatile boiler additive to retard corrosion in pipes	See chemical names
Agar-Agar	Stabilizer	Sufficient for purpose
Animal & Vegetable Oil	Shortening	Sufficient for purpose
Methyl Polysilicone	To retard foaming	10 ppm
Ascorbic acid	Accelerate color fixing in curing	7½ ozs. to 100 gals. pickle; ¾ oz. to 100 lbs. chicken meat
Benzoate, sodium: benzoic acid	To retard flavor reversion	0.1%
Butylated hydroxyanisole	Antioxidant: To retard rancidity development	0.1%
Butylated hydroxytoluene	Antioxidant: To retard rancidity development	0.1%
Bicarbonate of soda	To neutralize excess acidity; cleaning vegts.	Sufficient for purpose
Caramel	Flavor	Sufficient for purpose
Carbon (purified charcoal)	Refining	Sufficient for purpose
Caseinate, sodium	Binder and extender	Sufficient for purpose
Cellulose gum (carboxymethyl cellulose)	Extender, stabilizer	Sufficient for purpose
Chlortetracycline	To retard spoilage	7 parts per million
Citric acid	Synergist: To increase effectiveness of antioxidants	0.01%
Citric acid and sodium citrate	Prevents coagulation	0.2%
Condiments	To develop flavor	Sufficient for purpose
Sodium chloride	Flavoring and deboning process	Sufficient for purpose
Coffee extract	To develop flavor	Sufficient for purpose
Coloring material, vegetable and synthetic	Casings and ink only	Sufficient for purpose
Corn syrup	Flavor, cure	2.5%
Corn syrup dried	Flavor, cure	2.0%
Cyclamate, sodium	Sweetener	0.15%
Cyclohexylamine	To retard corrosion	10 ppm from approved feeder
Dextrose	Flavor; cure seasoning	Sufficient for purpose
Diacetyl	Flavor	Sufficient for purpose

ADDITIVE	PURPOSE	AMOUNT
Diatomaceous earth	Refining	Sufficient for purpose
Dry ice (carbon dioxide solid)	Cooling	Sufficient for purpose
Ficin	Soften tissue	Sufficient for purpose
Flavoring (chemical and synthetic)	Flavor	Sufficient for purpose
Flour (rice, potato, wheat)	Thickener	Sufficient for purpose
Fullers earth	Refining	Sufficient for purpose
Gelatin	Thickener	Sufficient for purpose
Glycerol	Inhibit drying; manufacture of mono- and di-glycerides	Sufficient for purpose
Glycerol lactopalmitate, etc.	A type of mono- and di-glycerides	Sufficient for purpose
Gums, vegetable (Tragacanth, karaya, etc.)	Emulsifying agent; binder	Sufficient for purpose
Hydrolyzed plant protein	Flavor	Sufficient for purpose
Isoascorbic acid	Accelerate color fixing in curing	7½ ozs. to 100 gals. pickle; ¾ oz. to 100 lbs. chicken meat
Lactic acid	To develop flavor	0.5%
Lecithin	To retard rancidity development; emulsifier	Sufficient for purpose
Lignin	Loosen scale	Sufficient for purpose
Malt syrup	Flavor; cure	2.5%
Mono- and di-glycerides	Emulsifiers	Sufficient for purpose
Monoisopropyl citrate	To increase effectiveness of antioxidants	0.01% in lard and shortening
Monosodium glutamate	Flavor	Sufficient for purpose
Nitrate of soda or potassium	Source of nitrite	See sodium or potassium nitrate
Nitrite of soda or potassium	Fix color	See sodium or potassium nitrite
Nitrogen	Exclude oxygen	Sufficient for purpose
Nordihydroguaiaretic acid	Antioxidant: To retard rancidity development	0.01%
Papain	Soften tissue	Sufficient for purpose
Phosphates: disodium; sodium hexa- meta-; tripoly-; sodium pyro-; sodium acid pyrophosphate	Decrease amount of cooked-out juices	5.0% in pumping pickle; 0.5% in canned chopped chicken
Phosphate, sodium hexameta-	Retard scale formation in pipes	10 ppm from approved feeder
Phosphoric acid	Synergist: To increase effectiveness of antioxidants	0.01%
Propyl gallate	Antioxidant: To retard rancidity development	0.01%
Resin guaiac	Antioxidant: To retard rancidity development	0.1%
Silica gel	Anti-caking agent	0.5%
Sodium ascorbate; sodium isoascorbate	Accelerate color fixing in curing	7½ ozs. to 100 gals. pickle; ⅞ oz. to 100 lbs. chicken meat; 10% soln. to surface of cured product prior to packaging
Sodium bicarbonate	To neutralize excess acidity; cleaning vegts.	Sufficient for purpose
Sodium caseinate	Binder and extender	Sufficient for purpose
Sodium or potassium nitrate	Source of nitrite	7 lbs. to 100 gals. pickle; 3½ ozs. to 100 lbs. chicken meat (dry cure); 2¾ ozs. to 100 lbs. chopped chicken meat

ADDITIVE	PURPOSE	AMOUNT
Sodium or potassium nitrite	Color fixing	200 ppm (0.2%) in product; 2 lbs. to 100 gals. pickle; 1 oz. to 100 lbs. chicken meat (dry cure); ¼ oz. to 100 lbs. chopped chicken meat
Sodium sulfoacetate derivatives of mono- and di-glycerides	Emulsifier	0.5%
Sorbitol	Retard drying	Sufficient for purpose
Starch	Thickener	Sufficient for purpose
Stearyl citrate	To protect flavor	0.15%
Sugars, approved (sucrose and dextrose)	Flavoring; curing; seasoning	Sufficient for purpose
Tannic acid	Refining; loosen scale	Sufficient for purpose
Tapioca	Thickener	Sufficient for purpose
Tocopherols	Antioxidant: To retard rancidity development	0.03%
Yeast (dry and wet)	Flavor	Sufficient for purpose

Food coloring agents approved for use under Food, Drug and Cosmetic Act

Colors certified for use in food without restriction.

FD&C Green No. 1
FD&C Green No. 2
FD&C Green No. 3
FD&C Yellow No. 5
FD&C Yellow No. 6
FD&C Red No. 1
FD&C Red No. 2
FD&C Red No. 3
FD&C Red No. 4
FD&C Blue No. 1
FD&C Blue No. 2
FD&C Violet No. 1
Lakes (FD&C)

Colors certified for use in foods with restriction.

(1) Batches of Citrus Red No. 2 shall be certified under the regulations in this section for use only for coloring the skins of oranges that are not intended or used for processing (or, if so used, are designated in the trade as "packing-house elimination"), and that meet minimum maturity standards established by or under the laws of the States in which the oranges are grown.

(2) Oranges colored with Citrus Red No. 2 shall bear not more than 2.0 parts per million of such color, calculated on the basis of the weight of the whole fruit.

(d) A batch of a mixture that contains Citrus Red No. 2 may be certified for use only for coloring the skins of oranges in accordance with the regulations in this section if:

(1) Each coal-tar color used as an ingredient in mixing such batch is from a previously certified batch, and such color has not changed in composition in any manner whatever since such previous certification, except by mixing into such batch of mixtures; and

(2) Each diluent in such batch of mixture is harmless and suitable for use therein.

(e) The label on each package of Citrus Red No. 2 certified in accordance with the regulations in this part shall bear, in addition to other words, statements, and information required by regulation, statements prescribing the limitations of use set forth in paragraph (c) (1) and (2) of this section.

Co-operative Extension work in Agriculture and Home Economics, College of Agriculture, University of California, and United States Department of Agriculture co-operating. Distributed in furtherance of the Acts of Congress of May 8, and June 30, 1914. George B. Alcorn, Director, California Agricultural Extension Service.

5m-6,'60(B0400)HR